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Technical Report 916

An Analysis of Skill Transfer for Tank Gunnery Performance Using TOPGUN, VIGS, and ICOFT Trainers

Janet J. Turnage and James P. Bliss
University of Central Florida

October 1990

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US ARMY
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PM TRAINING DEVICES

**United States Army Research Institute
for the Behavioral and Social Sciences**

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A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

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Research accomplished under contract for the Department of the Army

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UNCLASSIFIED

ITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

EPORT SECURITY CLASSIFICATION lassified	1b RESTRICTIVE MARKINGS --
ECURITY CLASSIFICATION AUTHORITY ECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
RFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Technical Report 916
IAME OF PERFORMING ORGANIZATION versity of Central Florida — 6b. OFFICE SYMBOL (If applicable) --	7a. NAME OF MONITORING ORGANIZATION U.S. Army Research Institute PM TRADE Field Unit at Orlando, Florida
DDRESS (City, State, and ZIP Code) . Box 25000 ando, FL 32816	7b. ADDRESS (City, State, and ZIP Code) PMTRADE-E/ARI 12850 Research Parkway Orlando, FL 32826-3276
IAME OF FUNDING / SPONSORING)RGANIZATION Project Manager Training Devices — 8b. OFFICE SYMBOL (If applicable) --	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER IST/PMTRADE/ARI Simulation Networking Contract #N61339-88-G-0002
DDRESS (City, State, and ZIP Code) RADE-E/ARI 50 Research Parkway ando, FL 32826-3276	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62785A; PROJECT NO. 790; TASK NO. 8604A & IST TASK #4; WORK UNIT ACCESSION NO. N/A

ITLE (Include Security Classification)
Analysis of Skill Transfer for Tank Gunnery Performance Using TOPGUN, VIGS, and ICOFT
iners

ERSONAL AUTHOR(S)
nage, Janet J.; and Bliss, James P.

TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
al	FROM 88/08 TO 89/07	1990, October	

UPPLEMENTARY NOTATION
versity of Central Florida, Institute for Simulation and Training, 12424 Research
kway, Suite 300, Orlando, FL 32821.

COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	Skill transfer	VIGS
			Tank gunnery performance	ICOFT
			TOPGUN	Training devices (Continued)

BSTRACT (Continue on reverse if necessary and identify by block number)

This study was performed to determine (1) whether performance improves during part-task
k gunnery training on TOPGUN and VIGS devices; (2) whether TOPGUN performance transfers
VIGS performance, and vice versa; (3) whether training performance on VIGS and TOPGUN
nsfers to gunnery performance on a high-fidelity trainer--the Institutional Conduct-of-
e Trainer (ICOFT); (4) which sequence of training (TOPGUN-VIGS or VIGS-TOPGUN) shows
ter transfer to ICOFT; and (5) whether selected aptitude, ability, motivational, and
ographic measures predict TOPGUN, VIGS, and ICOFT performance.

Sixty student subjects were randomly assigned to three groups. Each group of 20 sub-
ts was screened for colorblindness and completed a battery of predictor tests consisting
the VISTECH contrast sensitivity test (four replications), the Automated Performance
t System (APTS, three replications), a short version of the Armed Services Vocational
itude Battery (ASVAB), and the Work and Family Orientation (WOFO) (Continued)

DISTRIBUTION / AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
NAME OF RESPONSIBLE INDIVIDUAL ephen L. Goldberg	22b TELEPHONE (Include Area Code) AV 960-8173 — 22c. OFFICE SYMBOL PERI-IF

orm 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

ARI Technical Report 916

18. SUBJECT TERMS (Continued)

Prediction of gunnery performance	VISTECH
APTS	Performance measurement
ASVAB	Reliability stability

19. ABSTRACT (Continued)

Questionnaire. The two experimental groups (TOPGUN-first and VIGS-first) received two training trials per day for 2 days on either TOPGUN or VIGS and then were switched to the alternate device for training on the following 2 days. Finally, all subjects received approximately 2.5 hours of familiarization and testing on the ICOFT and completed post-test opinion questionnaires.

Results indicated that (1) performance improved at equal rates during TOPGUN and VIGS training; (2) there was significant transfer between most TOPGUN and VIGS performances, with no apparent superiority to either device; (3) except for speed measures, TOPGUN and VIGS training transferred to ICOFT; (4) there were no apparent differences between the TOPGUN-VIGS or VIGS-TOPGUN sequences of training; and (5) highly reliable predictor tests (e.g., code substitution and reaction time tests from APTS; contrast sensitivity test from VISTECH; and "auto and shop information" and "mechanical comprehension" from ASVAB) proved to be the best indicators of gunnery performance on the various devices despite generally low multiple correlations.

Technical Report 916

An Analysis of Skill Transfer for Tank Gunnery Performance Using TOPGUN, VIGS, and ICOFT Trainers

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October 1990

Army Project Number
2Q162785A790

Human Performance Effectiveness
and Simulation

FOREWORD

A primary mission of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) PM TRADE Field Unit at Orlando is to enhance soldier performance by obtaining maximum training value from Army simulation and training devices. This research investigated the use of three devices in conducting M1 tank gunnery training. These devices were two part-task trainers, VIGS and TOPGUN, and the full-fidelity Institutional Conduct-of-Fire-Trainer (ICOFT). The objectives of the research were to determine the degree of gunnery skills transfer between the part-task gunnery trainers and the full-fidelity gunnery simulator and to identify possible predictors of tank gunnery performance. ICOFT criterion performances were examined for two pretraining groups (either TOPGUN first, then VIGS, or VIGS first, then TOPGUN) and a control group to discover which pre-training sequence leads to better performance.

This task was performed under contract in response to the joint PM TRADE and ARI Broad Agency Announcement (May 1988) relating to the production of more efficient and effective training systems and devices. PM TRADE funded and administered this contract, while ARI monitored the technical aspects of the research, providing guidance to the contractor as required. The research results were delivered to the chief of PM TRADE's Research and Engineering Division and to the PM Close Combat Training Systems.

This research demonstrates how different gunnery trainers may be used separately or together to improve gunnery skills. It also provides support for using less expensive part-task devices for training basic gunnery skills that might otherwise require the use of a full-fidelity simulator. The results should be of interest to the armor school, because they must teach basic gunnery skills to their students, and to both active and reserve armor units because they must make optimal use of limited training time and resources.

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ACKNOWLEDGMENTS

This paper represents the combined efforts and ideas of many people, without whose help this project would not have been completed. To name them all would be impossible, but certain individuals definitely require acknowledgment and thanks for their assistance.

Experimenter: Valerie Orten, for help and reliability in scheduling and running subjects;

ARI Personnel (Fort Knox and Orlando): Dr. Bob Witmer, Dr. John Boldovici, Dr. Bruce Knerr, and Ron Kraemer for expertise in tank gunnery research activities;

G.E. ICOFT Support: Victor Tisdel, Melinda Carlie, David Jones, Clayton Rash, and Conrad Holloway for contract and logistical support;

Subject Matter Experts: John Anderson and Michael Kosavich for software and equipment support concerning VIGS and TOPGUN, respectively;

Institute for Simulation and Training Personnel: Dan Beistel, Kay Mullally, and Ernest Smart, for contractual assistance and support;

Data Coders: Christine Adkins, Kristin Markum, Jeanne Weaver, Tony Glaser, Joan Dunham, Sylvia Multari, and Christopher Saindon, for conscientious data entry;

Subject Drivers (to Daytona): Diana Matty, Dan Lucero, Kenny Hudson, and Jeff Carey.

Essex Corp. Employees: Martin Smith, for valuable help with statistical analyses, and Robert S. Kennedy, for imparting extensive scientific and technical knowledge to the project.

In addition, two others must be mentioned: Halim Ozkaptan was instrumental in formulating this project and Connie Curry's typing capabilities were greatly appreciated.

AN ANALYSIS OF SKILL TRANSFER FOR TANK GUNNERY PERFORMANCE USING TOPGUN, VIGS, AND ICOFT TRAINERS

EXECUTIVE SUMMARY

Research Requirement:

The research reported here represents an investigation of the training effectiveness of two part-task tank gunnery training devices, the Videodisk Gunnery Simulator (VIGS) and the TOPGUN trainer. Each of these devices is designed to train and sustain M1 tank gunnery skills.

The general purposes of the study were to determine (1) whether performance improves during TOPGUN and VIGS training; (2) whether TOPGUN performance transfers to VIGS performance, and (3) whether TOPGUN performance transfers to gunnery performance on a full-fidelity trainer, the Institutional Conduct-of-Fire Trainer (ICOFT); (4) which sequence of training (TOPGUN or VIGS-TOPGUN) shows better transfer to ICOFT; and (5) whether selected aptitude, ability, motivational, and demographic measures predict TOPGUN, VIGS, and ICOFT performance.

Procedure:

Sixty student subjects were randomly assigned to three groups. Each group of 20 subjects reported for approximately 4 hours of pretesting (Phase 1), 8 hours of training and transfer on TOPGUN and VIGS (Phases 2 and 3), and 2 hours of ICOFT testing (Phase 4). Control subjects' procedures were the same except no VIGS or TOPGUN training was given. In Phase 1, subjects were screened for colorblindness, then completed a battery of predictor tests consisting of the VISTECH contrast sensitivity test (four replications), the Automated Performance Test System (APTS, three replications), a short version of the Armed Services Vocational Aptitude Battery (ASVAB), and the Work and Family Orientation (WOFO) Questionnaire. In Phase 2, the two experimental groups (TOPGUN-first and VIGS-first) received two training trials per day for 2 days on either TOPGUN or VIGS and then were switched to the alternate device for training on the following 2 days (Phase 3). In Phase 4, all subjects received approximately 2.5 hours of familiarization and testing on the ICOFT, then completed post-test opinion questionnaires.

Performance measures for TOPGUN and VIGS included elevation and azimuth aiming errors (in mils), time to fire (time from presentation of the target to firing the first round), time to kill, first round hit percentage, and a composite performance score.

For ICOFT, time to fire, time to kill, hit percentage, and two composite performance scores, target acquisition (TA) error and reticle aim (RA) score, were used.

Findings:

We found that (1) performance improved at equal rates during TOPGUN and VIGS training; (2) there was significant transfer between most TOPGUN and VIGS performances, with no apparent superiority to either device; (3) except for speed measures, TOPGUN and VIGS training transferred to ICOFT; (4) there was no apparent difference between the TOPGUN-VIGS or VIGS-TOPGUN sequences of training; and (5) highly reliable predictors (e.g., code substitution and reaction time tests from APTS, a contrast sensitivity test from VISTECH, and two ASVAB scores) proved to be the best predictors of gunnery performance on the various devices despite generally low multiple correlations.

Utilization of Findings:

Results were discussed in light of Boldovici's (1987) guidelines for transfer research with military devices. This study particularly confirms Boldovici's suggestions that future research of tank gunnery trainers should pay more attention to time-on-task (i.e., stability of performance) and measurement reliability to increase the power of statistical tests and ultimately identify the critical tank gunnery tasks and skills that can enhance gunner selection and training.

AN ANALYSIS OF SKILL TRANSFER FOR TANK GUNNERY PERFORMANCE USING TOPGUN, VIGS, AND ICOFT TRAINERS

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AN ANALYSIS OF SKILL TRANSFER FOR TANK GUNNERY PERFORMANCE USING TOPGUN, VIGS, AND ICOFT TRAINERS

INTRODUCTION

Gunnery Training Using Training Devices

The primary function of the Army is to train and maintain combat-ready troops. To accomplish effective training requires knowledge of which soldiers need training, which tasks need to be trained, when training should be scheduled, which training devices to utilize, and how much training is needed to acquire and maintain proficiency on needed skills.

It is generally recognized (U.S. Army Armor School, 1981) that, because of high ammunition costs and limited availability of equipment and live-fire ranges, it is difficult to attain and sustain required tank gunnery proficiency levels. For these reasons, considerable attention has recently focused on the development of tank gunnery training devices that permit extended firing practice while saving costly ammunition (Department of the Army,1984; U.S. Army Armor Center, 1984).

The research reported here represents an investigation of the training effectiveness of two of these devices, the Videodisk Gunnery Simulator (VIGS) and the TOPGUN trainer. Each of these devices is designed to train and sustain M1 tank gunnery skills.

VIGS. The M1 VIGS is manufactured by E.C.C. Corporation in Orlando, Florida, and is designed to act as a part-task trainer for M1 or M1A1 tank gunners. The trainer was designed to train gunners to engage targets from a stationary tank as a substitute for training previously provided in early stages of the annual gunnery training cycle (Witmer, 1988). VIGS is a part-task, table-top medium-fidelity device equipped with a single primary sight and many of the switches and controls that are used in live-fire engagements (Witmer, 1988). The basic components of the M1 VIGS are shown in Figure 1. The components include a gunner's console, a videodisk player for generating target scenes, and a floppy disk drive to allow software control. Optional components used in a prototype research version of the M1 VIGS include a separate operator's station consisting of an operator's terminal for initiating engagements, a performance monitor for observing the gunner's performance in real time, and a printer for producing a hard copy of the gunner's performance (Witmer, 1988). These components are illustrated in Figure 2.

Witmer (1988) evaluated the training and transfer between VIGS and the Unit Conduct of Fire Trainer (UCOFT), which simulates many functions of the actual tank. Using twenty-four soldiers with no previous M1 gunnery experience, divided into two groups of twelve, Witmer initially trained one group as gunners on the VIGS and then tested on UCOFT, while the other group

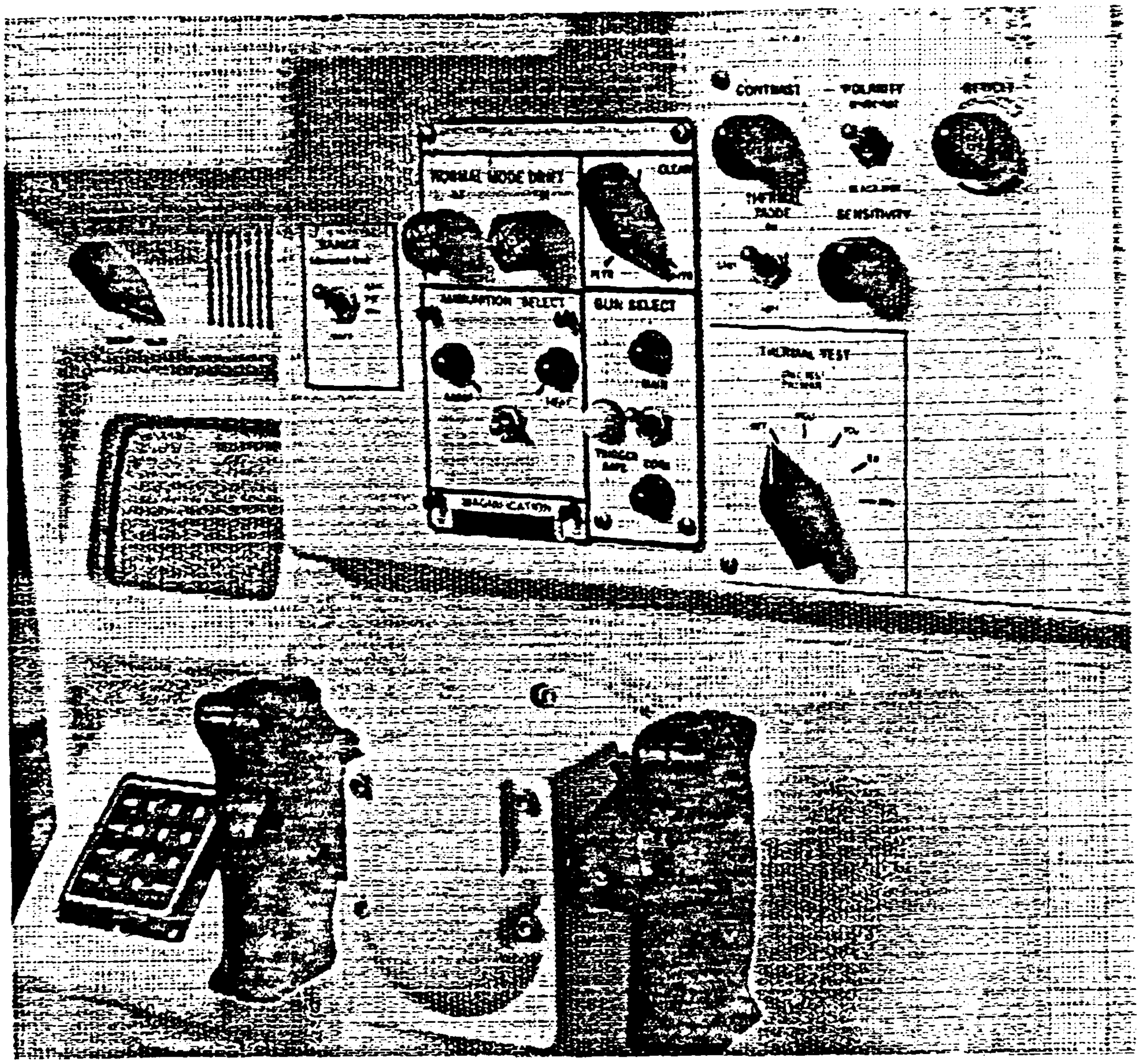


Figure 1. M1 Videodisk Gunnery Simulator Basic Components

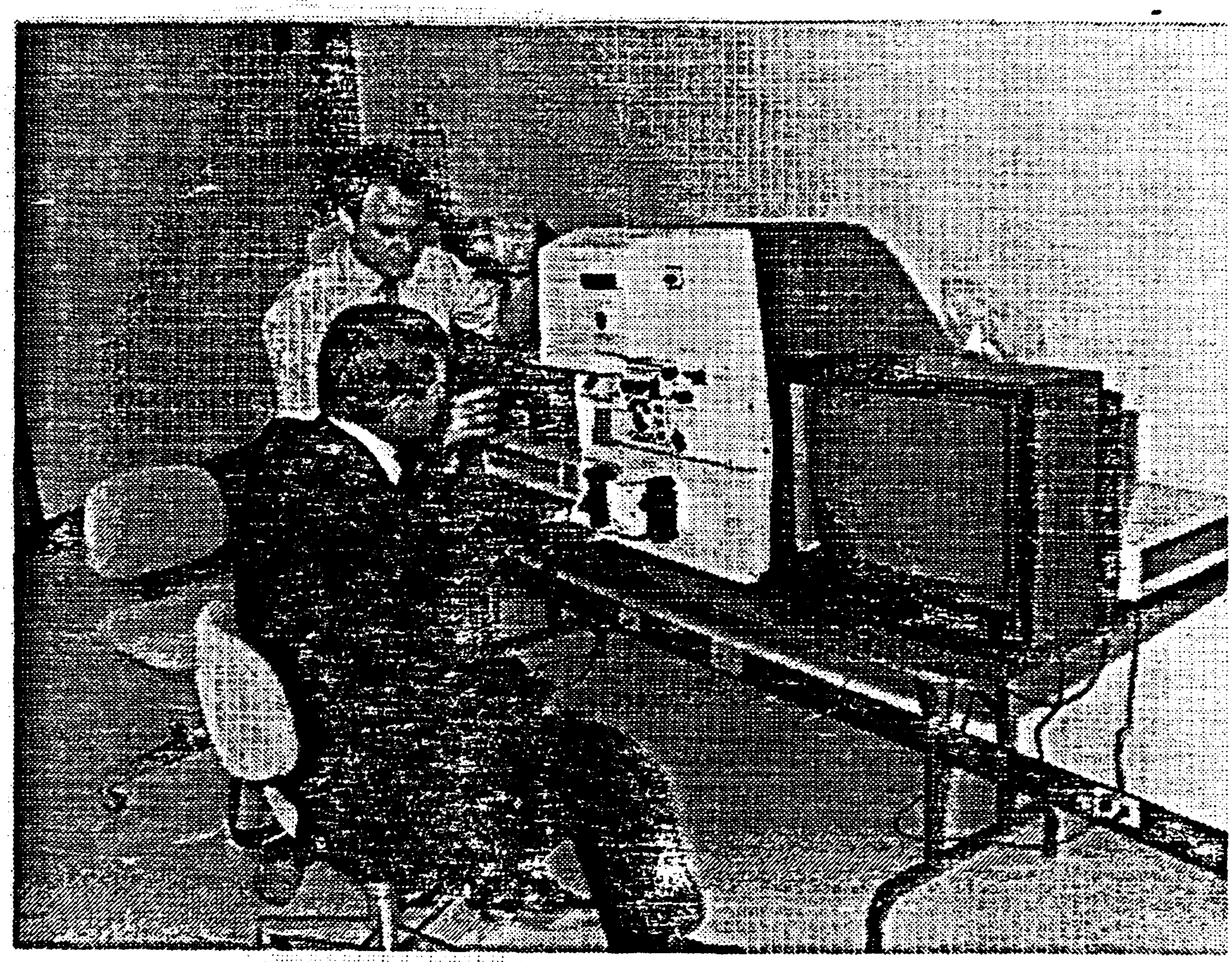


Figure 2. M1 Videodisk Gunnery Simulator Optional Components

trained on UCOFT and then were tested on the VIGS. Although Witmer found significant performance improvements on each device as well as significant correlations between UCOFT and VIGS performances, prior training on VIGS did not result in increased performance levels on UCOFT. This failure of skills learned on one device to transfer to the other device was interpreted as perhaps being due to insufficient practice on the first device or to fundamental differences in responses required by the two devices (Witmer, 1988).

TOPGUN. The TOPGUN trainer is a low cost tank gunnery prototype, designed by NKH corporation in Carlsbad, California, under a joint ARI-DARPA program. Costing about $5,934 each, TOPGUN is an arcade-type part task trainer for the gunner position designed as a sustainment trainer for crewmen already familiar with tank gunnery operations. The trainee engages single, multiple, moving and stationary targets in response to an automated "tank commander's" instructions. The tank commander is TOPGUN's onboard computer which evaluates threats, assigns them priority, and directs the engagement accordingly. The trainer is an updated version of its predecessor, Battlesight, yet similar in many ways. Figure 3 shows the side view of the TOPGUN simulator. The device uses computer-generated graphics and sound effects. The nineteen-inch color cathode ray tube (CRT) is partially masked to provide two distinct display areas, a reticle area and a gaming area (Figure 4). Gunner's control handles similar to those found in the M1 tank are used to track targets and fire main gun rounds.

Although TOPGUN has the potential capability of providing cost-effective, home-station gunnery training for Reserve Component (RC) armor crewmen and others, no empirical data exist at present to examine its purported capabilities. Research programs developed by the Army Research Institute at Fort Knox and Boise have provided preliminary data (Kraemer, personal communication, 1988).

The only preliminary results available from these studies are from the Gowen Field Training Lab (Boise) where a training transfer study between TOPGUN and COFT was conducted (Kraemer, personal communication, 1989). Soldiers in the experimental groups received either one or three sessions of TOPGUN training prior to being tested on the COFT simulator, while soldiers in the control group received no TOPGUN training. All training used the gunner's auxiliary sight (GAS) rather than the primary sight because it is more difficult to train. Results demonstrated that soldiers who received prior TOPGUN training performed better on COFT using stationary targets, while no transfer was shown for moving targets. Although data showed no transfer for moving targets as a whole, there were several possible reasons advanced for the lack of transfer. First, there were difficulties involved in using the auxiliary sight. For example, when applying manual

lead, there were differences in average target speed between TOPGUN and COFT targets. Also, TOPGUN has a narrower field of view and larger reticle than COFT. Overall, learning was demonstrated across sessions for all types of targets within TOPGUN, and performance on TOPGUN did correlate with performance on COFT for both speed and accuracy measures. Correlations were higher for speed than accuracy measures, but the research failed to report the magnitude or significance level of these correlations.

UCOFT. The M1 UCOFT is a high-fidelity trainer that provides practice for the gunner and tank commander on many of the required gunnery tasks. The major UCOFT components are illustrated in Figure 5 and include an instructor/operator's station, and enclosed crew station, a special purpose computer, and a general purpose computer (Instructor's Utilization Handbook, 1985). The instructor/operator's station contains separate monitors for the gunner's and tank commander's sights, an instructor's control terminal, and a printer. The tank gunner's station, illustrated in Figure 6, contains the Gunner's Primary Sight (GPS), the Gunner's Auxiliary Sight (GAS), and nearly all the switches and controls used by the gunner in the M1 tank (Witmer, 1988).

Transfer of Training

Transfer of training is central to the evaluation of new training devices and to the understanding of basic learning phenomena (Cormier & Hagman, 1987). However, there have been several design problems with past studies of transfer of Army training devices (Boldovici, 1987; Boldovici & Sabat, 1985). Among these are: 1) small numbers of subjects are used in the comparison; 2) subjects are not matched or randomly assigned; 3) groups are treated differently in respects other than those under investigation; 4) amount of practice is insufficient to affect proficiency; 5) measurement of criterion performance is unreliable; and 6) inappropriate analyses are used to estimate transfer. While the first three of these problems can be eliminated by better research designs and more careful application of those designs (Witmer, 1988), other sources of error are more problematic. For example, Klausmeir and Goodwin (1966) have pointed out the importance of demonstrating that initial learning has occurred before administering tests of training transfer. Initial learning can be demonstrated in two ways: by comparing pre-training and post-training scores or by measuring performance on a set of engagements over several repetitions. Especially difficult is the inherent unreliability of many criterion tests, such as live-fire tests where weapon system errors reduce target hits despite correct performance by the tank crew (cf. Fingerman, 1978). Demonstrating transfer of training should improve when evaluating training devices as opposed to live fire, however, because of improved reliability of

measurements through such features as automated scoring, recording of performance, and the capability to present the same scenarios under constant conditions to each soldier tested (Witmer, 1988). Finally, many inappropriate analyses are used to estimate transfer, such as chi-square analyses, correlation coefficients, and various transfer formulas (Boldovici, 1987). Gagne, Foster, and Crowley (1948) note, "The utilization of raw score values to express transfer is a procedure which has a number of advantages, chief among which is precision of meaning" (p. 98).

With these guidelines in mind, this study was designed to test skill acquisition and transfer from two part-task gunnery trainers, TOPGUN and the Videodisk Gunnery Simulator (VIGS), delivered in two different sequences, to criterion performance on a high-fidelity tank gunnery trainer, the Conduct of Fire Trainer (COFT).

Prediction of Performance

A secondary question of interest to Army training systems managers involves determining the individual difference factors that influence training device performance. Although studies (e.g., Eaton, Johnson, & Black, 1980) have found few predictors of training device or tank performance which explain significant amounts of criterion variance, in many cases criteria are flawed by unreliable performance measures (Turnage, Houser, & Hofmann, 1987), suggesting that improvement in performance measurement reliability can unmask individual difference predictors (Turnage & Lane, 1987).

Measuring and predicting complex task performance such as tank gunnery has been a challenge for researchers (Boldovici & Kraemer, 1974; Lane, 1986; Turnage, Houser, & Hofmann, 1987). Regardless of the particular setting, there are certain factors that make accurate performance measurement troublesome, including the identification, definition, and measurement of variables that may affect gunnery performance.

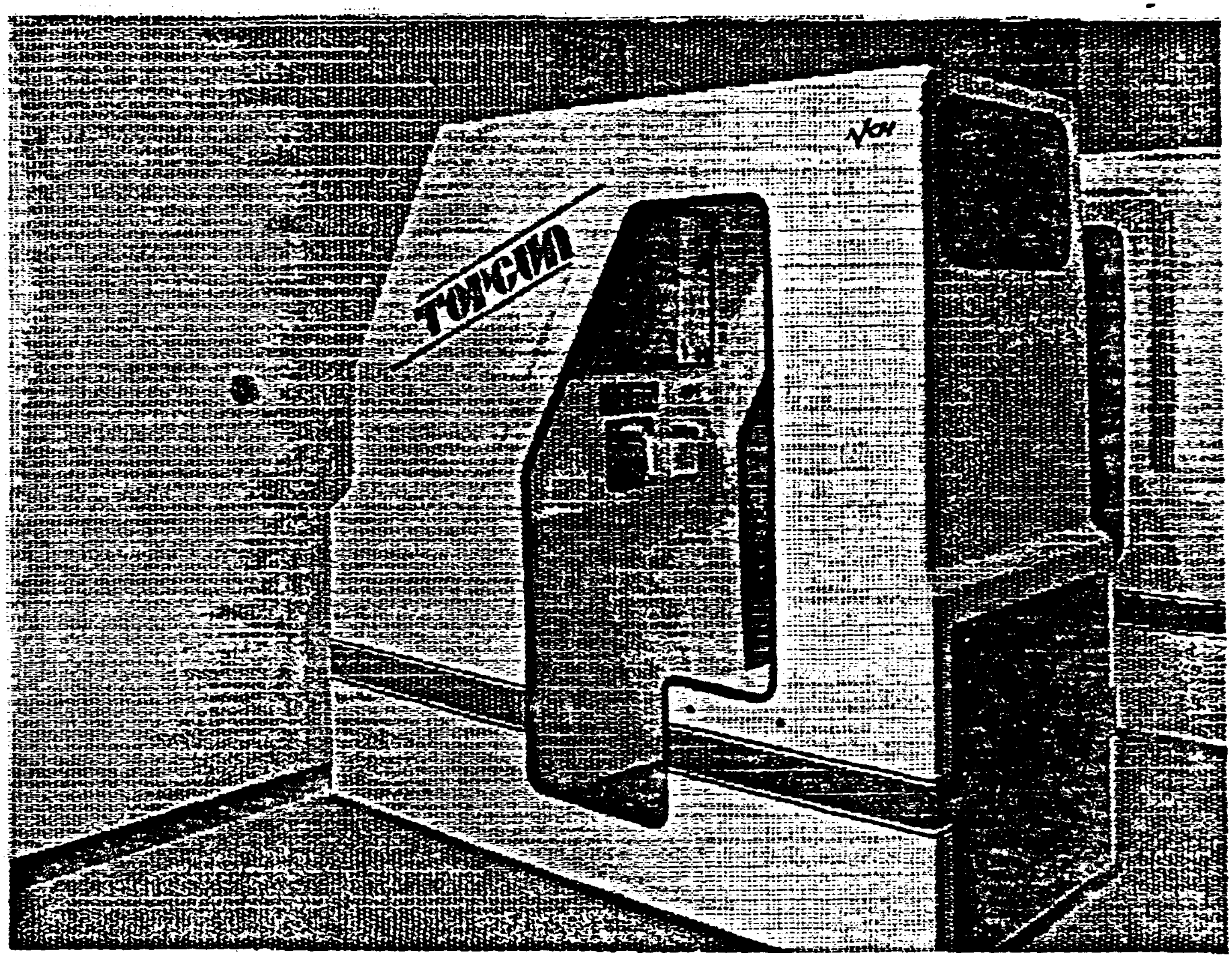


Figure 3. Side View of TOPGUN Simulator

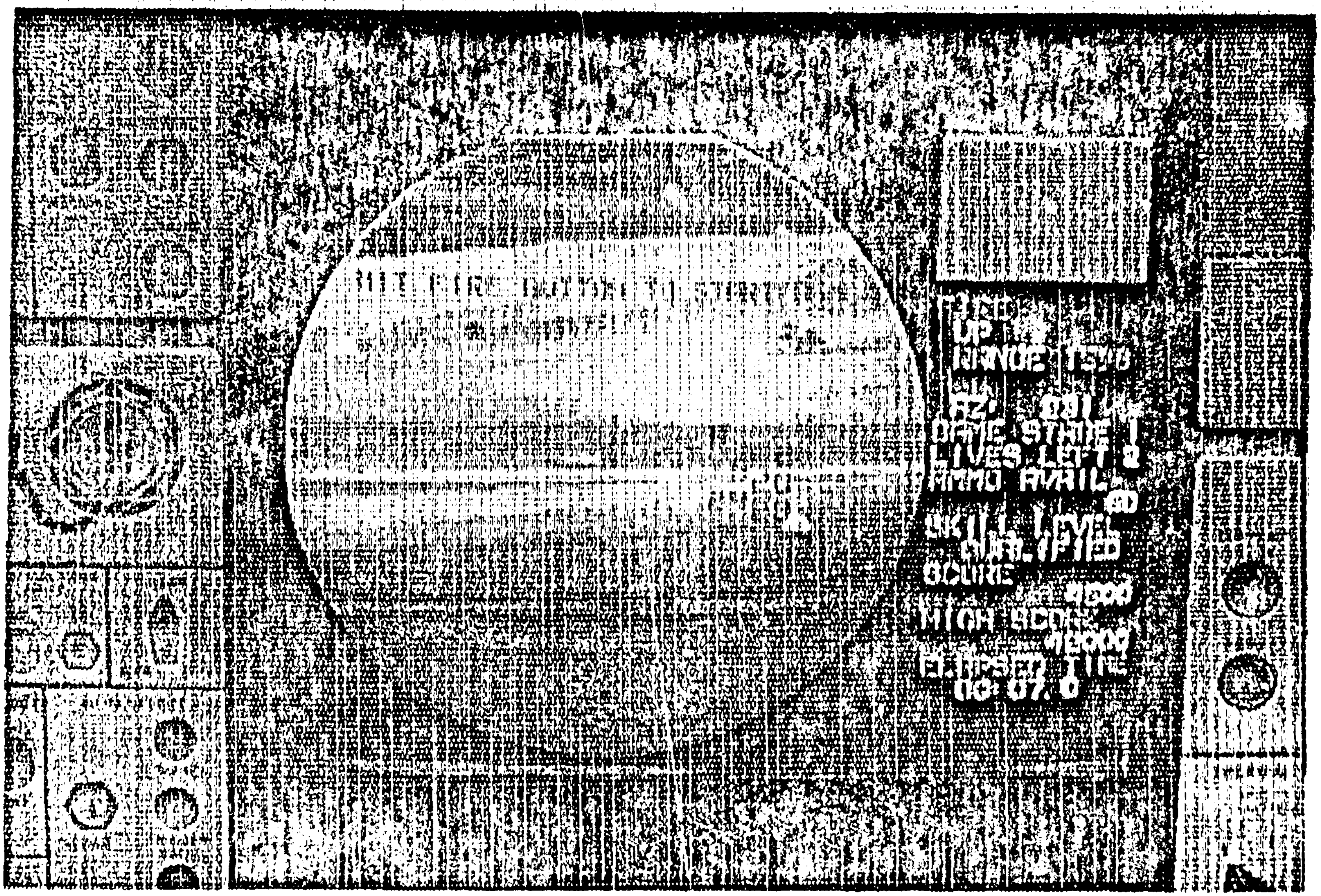


Figure 4. TOPGUN Display

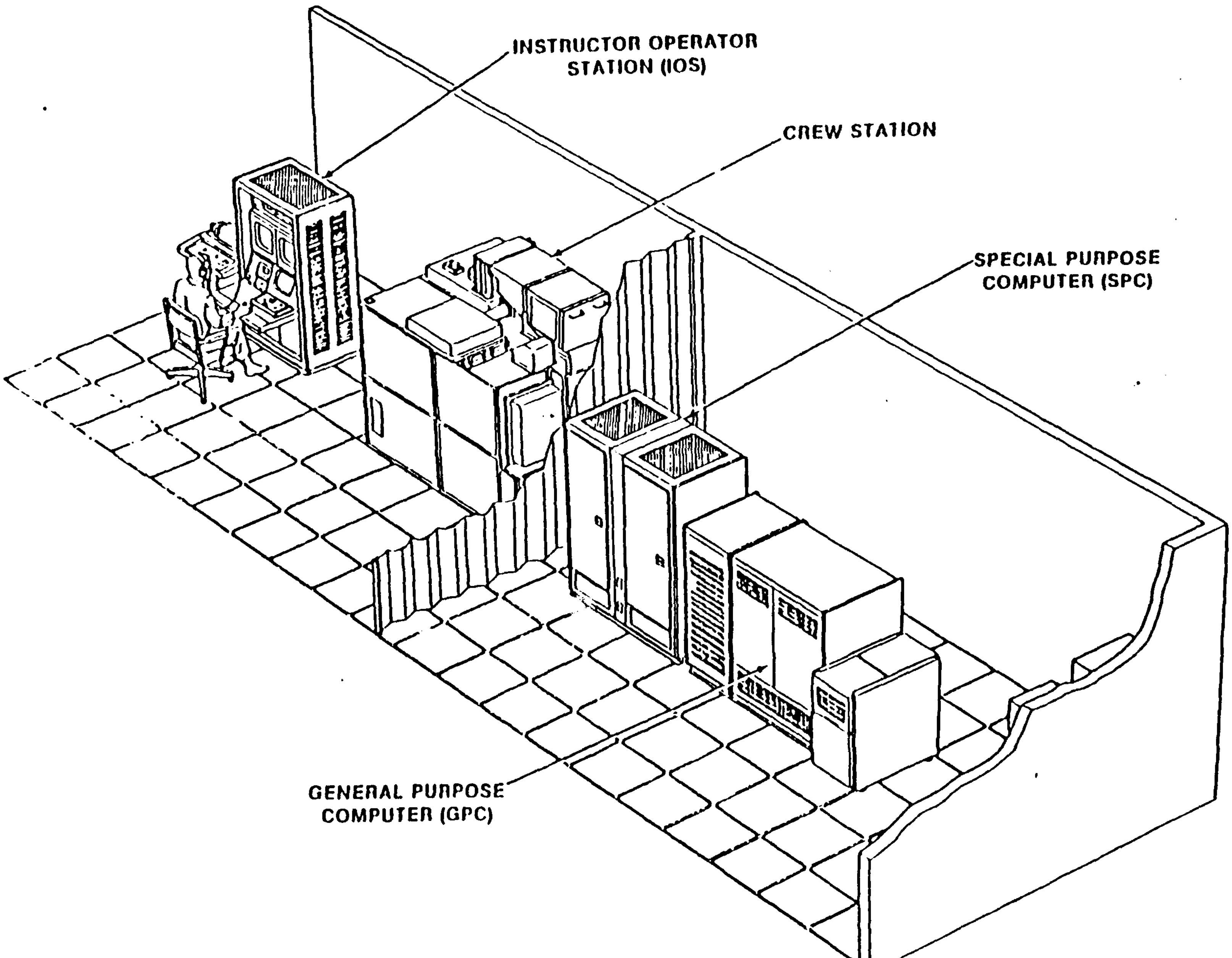
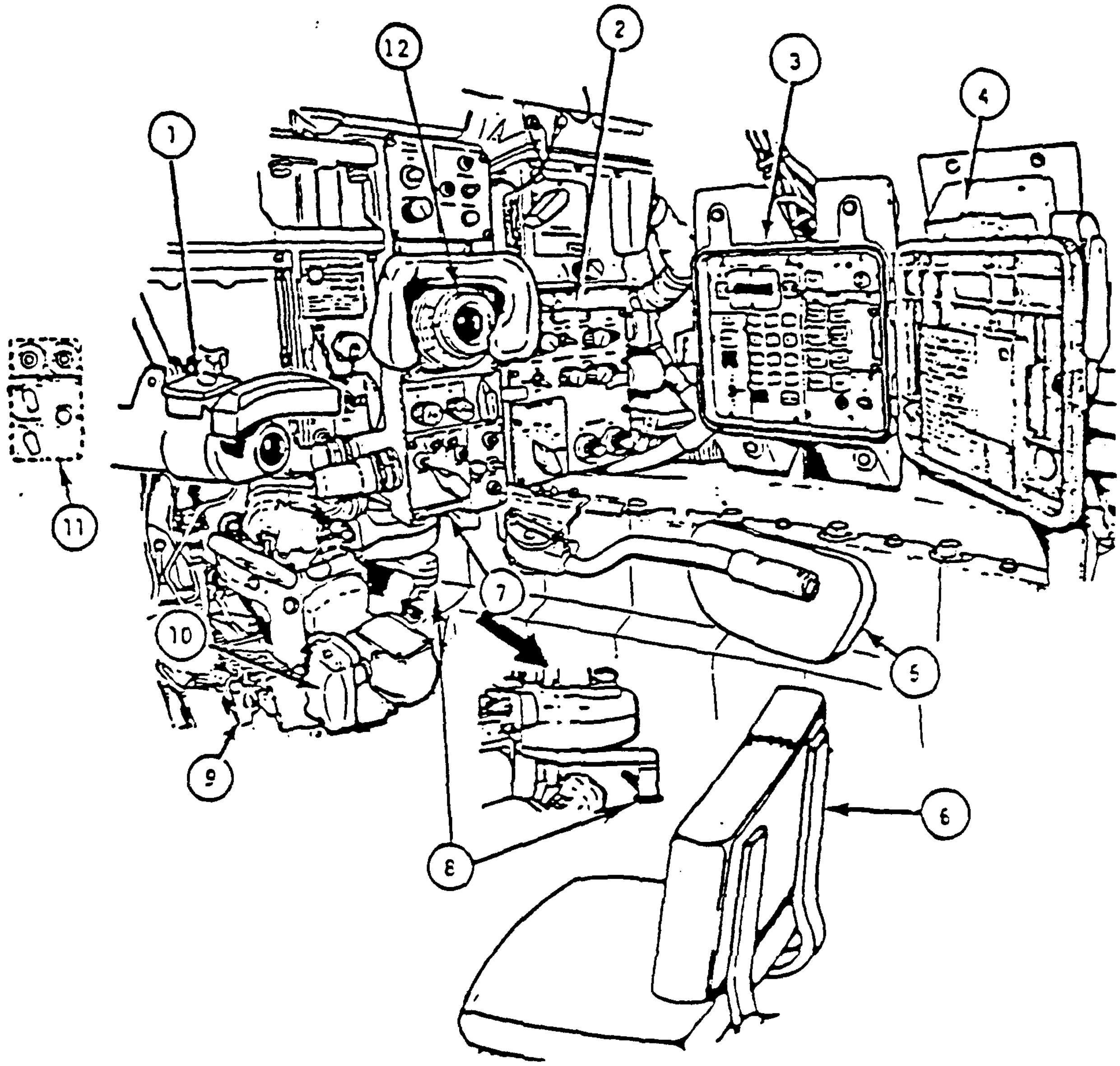


Figure 5. Unit Conduct-of-Fire Trainer Subsystems



1 GAS
2 TIS CONTROL PANEL
3 BALLISTIC COMPUTER CONTROL PANEL
4 INTERCOM CONTROL SET
5 CHEST REST
6 SEAT
7 GPS CONTROL PANEL
8 MANUAL TRAVERSE HANDLE
9 MANUAL ELEVATION HANDLE
10 GUNNER'S CONTROL HANDLE
11 GAS CONTROL PANEL
12 GPS

Figure 6. Unit Conduct-of-Fire Trainer Gunner's Station

For example, the selection process by which soldiers are identified for tank gunnery assignment must rely on an accurate assessment of the skills and aptitudes required for the job. Black and Graham (1987) provide a sample list of gunner aptitude/skill requirements for gunnery tasks in which hand-eye coordination is related to target tracking, visual acuity to target recognition, intelligence to computer procedures, perceptual skills to target identification, and reaction time to target engagement. They speculate that, only as we become proficient in determining the relative effects of the "aptitude pie", can we accurately identify personnel who will become superior performers in combat situations. However, variables other than skills and abilities can have marked effects on a gunner's performance. These factors relate to training and include motivation, amount of training, and type of training. Therefore, in this study a sampling of these variables was used to predict performances on gunnery tasks as measured by the three distinct training devices.

In the past, research concerning the prediction of tank crew performance has been inconclusive and flawed by measurement problems. Initial efforts to evaluate predictors of tank gunnery performance (e.g., Eaton, 1978; Eaton, Bessemer, & Kristiansen, 1979; Greenstein & Hughes, 1977) found that paper-and-pencil tests resulted in few significant correlations with gunnery scores. Black and Graham (1987) suggested that paper-and-pencil tests are limited "because they tap only perceptual and/or cognitive aptitudes, not the additional perceptual motor or psychomotor components of gunnery" (p. 5). Job sample testing, which consists of hands-on tests developed to measure certain critical aspects of the gunner's job performance, has been used in recent research efforts. Such tests, when used to evaluate M1 trainees (e.g., Biers & Sauer, 1982; Campbell & Black, 1982; Eaton, Johnson, & Black, 1980), have shown better prediction of performance by job incumbents than paper-and-pencil tests (Black & Campbell, 1982). In general, however, neither paper-and-pencil ability measures nor job sample tests have been particularly successful in predicting gunnery performances.

To date, accurate performance measurement of gunnery skills has been handicapped by the lack of appropriate criteria against which to validate predictor tests. Criterion measures used in previous studies include scores from live-fire gunnery exercises, Multiple Integrated Laser Engagements System (MILES) exercises, supervisory ratings, peer ratings, Skill Qualification Tests, and others (Black & Graham, 1987). However, there are numerous problems associated with current job performance criteria, due mainly to their inherent low reliabilities. Reliability can be defined as the extent to which, when performance is repeated, the same results are obtained. In many cases, however, such as when scores are obtained from live-fire gunnery exercises, measures of an individual's performance may not be consistent due to changes

in exercises, ammunition characteristics, equipment performance, and firing conditions. Any such inconsistencies reduce reliability by increasing error variance.

The effect of criterion unreliability is best illustrated by Spearman's (1904) correction for attenuation formula:

$$R_t = \frac{r_{xy}}{\sqrt{(r_{xx})(r_{yy})}}$$

where rxy is the observed relationship between a predictor, such as an ability score, and a criterion, such as operational performance, rxx is the reliability of the predictor, ryy is the reliability of the criterion, and Rt is the true relationship between the predictor and criterion.

Embedded within Spearman's formula are the two types of reliability that are necessary for accurate task performance measurement. Both are forms of internal reliability. The first, rxx, or predictor reliability, refers to the stability of the predictor. The second, ryy, refers to criterion reliability, where "criterion" is generally synonymous with operational performance, particularly in military training situations. To circumvent the problem of low predictive validity, it is necessary to improve the internal reliability of either the predictor or the criterion or both. In most cases, it is generally recognized that modification of the predictor measure is easier and less costly than modification of the criterion (Turnage, Kennedy, Gilson, Bliss, & Nolan, 1988).

One method in particular which has been suggested to alleviate the problems associated with low criterion reliability has been the use of surrogate measurement (Lane, Kennedy, & Jones, 1986). Surrogate measures, while related to the construct of interest, do not involve operations in common with the actual performance measures. Through this method of "substitution" surrogate measurement predicts portions of variance on the complex criterion task by performance on relatively simple tasks.

For surrogate measurement to be effective, Lane et al. (1986) suggest five characteristics that surrogate measures should demonstrate: 1) stability, 2) correlation with the performance construct, 3) sensitivity to the factors that would normally affect operational performance, 4) increased reliability, and 5) minimal use of training time. By fulfilling these requirements, it is suggested that surrogate measurement, while practically less valid, may tap more of the true variance of a field measure, due to its greater reliability.

Several studies (e.g., Kennedy, Wilkes, Dunlap & Kuntz, 1987; Turnage, Kennedy, Gilson, Bliss, & Nolan, 1988) have shown that stable performance measures from very simple tests were strongly related to global measures of intelligence and to simulated flight performance, thus supporting the concept of surrogate measurement.

In the present study, four predictor test sets were used because their demonstrated reliability might provide better prediction of tank gunnery performance, in line with the statistical assumptions underlying the previously-described correction-for-attenuation formula. Tests were selected to measure the fullest possible range of perceptual, cognitive, psychomotor, and motivational factors predictive of tank gunnery performance. In addition, three gunnery simulators which might be expected to accurately predict live-fire tank gunnery proficiency were used to provide criteria of gunnery performance. Based on Hoffman and Morrison's (1988) and Morrison and Hoffman's (1987) analyses of requirements for a device-based training and testing program for M1 Gunnery, preliminary analyses sought to define the domain of gunnery in terms of individual conditions and actions and evaluation of trainability on TOPGUN and VIGS (Appendix A, Appendix B), to update a task analysis of trainable behaviors on TOPGUN, VIGS, and COFT (Appendix C), and to determine the overall rankings of task transferability by broad categories as well as list untrainable behaviors (Appendix D). Because all three simulators were designed to train tank gunnery performance, performances measured on one device should predict performances on the other devices.

It was expected that the selection of reliable, task-related predictors and the use of training simulators to provide criteria which are more reliable than live-combat criteria would provide more valid selection and training prediction of gunnery personnel by indicating the required skill/aptitude substrates of proficient performance.

Research Objectives

The general purposes of this study were to determine: (1) whether TOPGUN training performance transfers to VIGS gunnery performance, and vice versa; (2) how TOPGUN and VIGS learning progresses over repeated trials, and how much TOPGUN and VIGS training is required to promote effective transfer; (3) the degree of transfer from two part-task gunnery trainers (TOPGUN and VIGS) to a high-fidelity trainer (ICOFT); and (4) whether selected ability and nonability tests predict performance on each device. The specific objectives were to answer the following questions:

1. Does performance improve during TOPGUN and VIGS

training?

2. Does TOPGUN performance transfer to VIGS performance, and vice versa?
3. Does training performance on VIGS and TOPGUN transfer to COFT performance?
4. Which sequence of training (TOPGUN-VIGS or VIGS-TOPGUN) shows better transfer to ICOFT?
5. Do selected aptitude, ability, motivational, demographic, and experience measures predict TOPGUN and VIGS performance?

METHOD

Subjects

Subjects were drawn from undergraduate and graduate classes located at the University of Central Florida in Orlando, Florida, on a voluntary basis in accordance with American Psychological Association Principles for Research with Human Subjects. An effort was made to solicit Army and Air Force ROTC students. The sign-up sheet, which was circulated in classes and fraternities, stated requirements for participation and informed applicants of the nature of the study and payment conditions (Appendix E). All subjects (n = 60) were male; there were 17 freshmen, 11 sophomores, 15 juniors, 13 seniors, and three graduate students. Eighteen of the subjects were drawn from Army (8) and Air Force (10) ROTC units on campus, with times in ROTC ranging from 1 month to 2 years. Two-thirds of the subjects indicated on a pretest questionnaire (Appendix F) that they played video games not at all or less than once per week. Subjects were screened for participation by a short test of color-blindness. They were informed as to the general nature of the experiment prior to testing, completed informed consent forms (Appendix G) prior to participation, and were paid five dollars per hour for their participation in the study.

Materials

Two part-task tank gunnery simulators (TOPGUN and VIGS) and one high-fidelity simulator (ICOFT) were used. An analysis by Hoffman and Morrison (1988) compared the skills trained by TOPGUN and VIGS. These skills can be grouped into five general categories: 1)procedural training (manipulating correct switches in their proper sequence), 2)target identification (identification of particular types of targets), 3)target detection, 4)target tracking (ability to keep reticle constantly on the target whether that target is moving or not), and 5)marksmanship training (accuracy and speed of target engagement). Drawing from that analysis, a further analysis was made of the particular tasks that are trainable on the devices, in some cases extending Hoffman and Morrison's analysis to

account for changes which have occurred in each devices's configuration, and to include COFT. The resulting task analysis was referred to earlier and is included as Appendix C.

TOPGUN. The TOPGUN trainer, as described earlier, is a prototype arcade-type part-task trainer for the gunner position. The trainee engages single, multiple, moving, and stationary targets in response to an automated "tank commander's" instructions. The tank commander is TOPGUN's onboard computer which evaluates threats, assigns them priority, and directs the engagement accordingly. TOPGUN operates in one of two modes: Recreational Mode, designed for dayroom type activity, which presents threats in a random manner; and Formal Mode, which allows the experimenter or instructor to program specific threat placements and kinematics. For this study, the formal mode was used in which a total of 36 targets were engaged, using a progressively more difficult mix of movements (stationary vs. moving), number of targets (single vs. multiple), and gunner sights (primary, thermal, and secondary). The specific target sequence used for TOPGUN is provided in Appendix H.

TOPGUN gives numerous performance measures, including the various speed and accuracy measures used in this experiment: time to fire, time to kill, azimuth and elevation errors from target center of mass, hit percentage, and a composite performance score which gives 100 points for each first round hit, 50 points for each second round hit, and 0 for poorer performance. Time to fire, time to kill, and aiming errors were based on first round data. Hit percentage was calculated as the number of first rounds hitting the target divided by the number of first rounds fired, and does not account for engagements for which no rounds were fired. This measure is not equivalent to hit percentage used by Witmer (1988), who defined first-round hit percentage as the total number of first-round hits divided by the number of engagements presented and total hit percentage as the total number of hits divided by the number of engagements. The composite performance score, on the other hand, included second round data.

VIGS. The M1 Videodisk Gunnery Simulator (VIGS) is also designed to act as a part-task trainer for M1 or M1A1 tank gunners. The VIGS trainer utilizes computer generated imagery (CGI) to present engagement scenes to the trainee. These scenes, along with target identification slides, are presented, modified, and stored via videodisk technology. In this way battle "missions" are created as collections of previously stored individual "lessons". The lessons, stored on videodisk, each present an engagement of approximately 45 seconds' duration. Through the use of synthesized speech, the "tank commander" informs the trainee of the target type, required ammunition, and fire directives. At the end of the engagement, trainees are provided detailed performance measures.

VIGS provides the same performance measures as TOPGUN with the exception that the composite performance score is calculated differently. For each mission, if the trainee fired accurately in the optimal time, he was given 100 points; point penalties were assessed for too many main gun fires (-5), wrong ammunition indexed (-30), fired at wrong target first (-5), ambushed the target (-5), fired before the "fire" command (-10), used the wrong GAS reticle (-30), or failed to lase (-5). If he took longer to fire than the optimal time, points were deducted as the difference from optimal time increased. A total of 41 targets were presented using a progressively more difficult mix of movements (stationary vs. moving), number of targets (single vs. multiple), and gunner sights (primary, thermal, and secondary). See Appendix H for the specific target sequence.

UCOFT. The M1 UCOFT (Unit Conduct-of-Fire Trainer) is a high-fidelity gunnery trainer that presents computer- generated target imagery for training in normal and degraded operational modes. Training is directed by an Instructional Subsystem which includes a library of preprogrammed exercises and an adaptive Evaluation System (UCOFT Utilization Handbook, 1985). For this study, six exercises of 10 engagements each were used to match as closely as possible target conditions used in the TOPGUN and VIGS trainers (Appendix H). Also, in this study, the Institutional form of UCOFT (ICOFT) was used because the ICOFT uses a standardized, synthetic tank commander in contrast to the UCOFT where real tank commander performance is free to vary and thus may contribute to unreliability of measurement.

Hoffman and Witmer (1989) discuss the conflicting merits of various UCOFT scoring systems. Selection and scoring of these indicators have in the past been tailored to specific research questions (e.g., Abel, 1987; Black & Abel, 1987; DuBois, 1987; Graham, 1986; Smith & Graham, 1987; Witmer, 1987). We chose a combination of single scores and composite scores to determine which were more reliable across exercises. The performance measures used in this study were time to fire, time to kill, number of rounds, and number of hits (from which hit percentage was subsequently calculated), and two composite measures, number of target acquisition errors, and reticle aim score. The composite Target Acquisition (TA) score is based on the time to acquire targets and number of target identification and classification errors. Reticle Aim (RA) is a composite function of time to fire the first round, time to kill, and magnitude of the aiming error. A composite gunnery index, advocated by Witmer (1988), has been evaluated by Bliss (1989, in preparation).

Graham (1986) showed that gunnery performance of inexperienced gunners could be reliably measured on the UCOFT using 31 engagements in different sequences. Retest reliability of six of nine gunnery performance measures exceeded .70, ranging

from .72 to .87. However, retest measures were only separated by a 10-minute rest period instead of the more common method of retesting on separate days.

APTS. The Automated Performance Test System (APTS) includes a battery of seven performance tests. The tests have been shown to be stable (<10 minutes testing time), reliable (r > .707), and of known and unique factorial content (e.g., Turnage, Kennedy, & Osteen, 1987). The APTS test battery is delivered on the Zenith Data Systems ZFL-181 portable microcomputer. The ZFL-181 contains 640K on board memory, two 720K 3.5 inch floppy drives, serial and parallel ports, an RGB interface, and 80 characters by 25 line supertwist, backlit LCD display, and is completely IBM PC compatible. The batteries are capable of powering the unit for 4.2 hours. Eighteen response measures are obtainable from the APTS, and subjects are required to press keys on the keyboard to provide answers and responses. The following APTS subtests used in this study are listed in their order of presentation:

Tapping (NPTAP; TFTAP). The tapping test is a motor skills performance test which has been highly recommended for inclusion in microbased repeated-measures batteries (Kennedy, Wilkes, Dunlap, & Lane, 1985). The subject is required to press the S and D keys alternately as fast as possible. Scoring is based upon the number of alternate keypresses recorded, as this insures that the subject is pressing more than one key. Subjects are instructed to perform some trials using their *"non-preferred" hand* (NPTAP) and some trials alternating taps between the index fingers of each hand (two-finger tap TFTAT).

Four-Choice Reaction Time (RT). The Four-Choice Visual Reaction Time test (Donders, 1968) involves the presentation of a visual stimulus and measurement of a response latency to the stimulus. The subject is instructed to respond as quickly as possible with a key press to a simple visual stimulus. The visual stimulus is preceded by an auditory signal and no decision making (disjunctive) regarding the stimuli is necessary. Reaction time is measured in milliseconds from the onset of the visual stimulus to the key press. The participant observes boxes on the screen until one changes appearance (from an "outlined" to a "filled" pattern). Then he presses the corresponding key. This test is described as of a perceptual nature.

Code Substitution (CS). The Code Substitution Test (Ekstrom, French, Harmon, & Derman, 1976) is derived by randomly assigning digits to nine letters. The subject's task is to repeat the assigned digit code when presented with the test letters. There is no response deadline, and each coding string remains on the screen for 30 trials. Code Substitution is described as a cognitive and perceptual-type task with visual search encoding and decoding, rote recall, and perceptual speed as important factors in performance. Previous studies of Code Substitution

(Pepper, Kennedy, Bittner, Wiker, & Harbeson, 1985) have indicated that the task is acceptable for use in repeated-measures research. Response time is recorded in milliseconds from the appearance of the probe letter until a response is made.

Grammatical Reasoning (GR). The Grammatical Reasoning test (Baddeley, 1968) involves five grammatical transformations on statements about the relationship between two letters, A and B. The five transformations included are: 1) active versus passive construction, 2) true versus false statements, 3) affirmative versus negative phrasing, 4) use of the verb "precedes" versus the verb "follows," and 5) A versus B mentioned first. There are 32 possible items arranged in random order. The subject's task is to respond "True" or "False", depending on the presentation of the statement. Performance is scored according to the number of transformations correctly identified. Grammatical Reasoning is described as measuring higher mental processes with reasoning, logic, and verbal ability as important factors in test performance. Previous studies with Grammatical Reasoning identified in Bittner, Carter, Kennedy, Harbeson, and Krause (1986) have indicated that the task is acceptable for use in repeated-measures research.

Simultaneous Pattern Comparison (PC). The Pattern Comparison Test (Klein & Armitage, 1979), which measures factors relating to target acquisition and visual search, requires the subject to examine a pair of eight-dot patterns and to determine whether they are "same" or "different". Patterns are randomly generated with similar and different pairs simultaneously presented in random order. Performance is scored according to the number of pairs correctly identified as similar or different. Pattern Comparison is described as a spatial ability important to perceptual performance. Response time is recorded in milliseconds measured from the appearance of the two patterns until a response is made. A review of Pattern Comparison studies (Bittner et al., 1986) indicated that the test is acceptable for use in repeated-measures research.

Manikin (MK). The Manikin test (Benson & Gedye, 1963) involves the presentation of a simulated human figure in either a full-front or full-back facing position. The figure is shown to have two easily differentiated hand-held patterns. One of the two patterns is the matched pair to a pattern appearing below the figure. The subject's task is to determine which hand of the figure holds a matching pattern and respond by pressing the appropriate arrow key (right arrow for right; left arrow for left). Pattern type, hand associated with the matching pattern, and front-to-back figure orientation are randomly determined for each trial. Bittner et al. (1986) recommended the use of the Manikin Test when latency scores are reported (in milliseconds

from the time the stimulus appears until a response is made. Performance is also based on the number of correctly matched pairs. The Manikin test is a perceptual measure of spatial transformation of mental images and involves spatial ability.

Mathematical Processing (MP). Mathematical Processing requires the subject to perform arithmetical operations as well as value comparison of numeric stimuli. The subject performs one to three addition and/or subtraction operations in a single presentation. A response is then made which indicates whether the total is greater or less than a prespecified value using the arrow keys. Number of correct responses and response latencies are recorded.

All tests were presented for 120 seconds, except for Four-Choice Reaction Time, which was presented for 90 seconds and both Tapping tests, which were presented for 20 seconds.

The stability and reliability of the APTS subtests have been demonstrated (Kennedy, Wilkes, Dunlap, & Kuntz, 1987; Turnage, Kennedy, & Osteen, 1987). In Kennedy et al.'s (1987) study, none of the APTS subtests' task definition reliabilities (average reliability of a task following the occurrence of correlational stability) were observed to fall below $r = .71$, and their three-minute reliabilities (reliabilities of stabilized tasks standardized to a three-minute administration base) were even higher ($r > .79$). Other examples of the APTS' reliability and stability are available as well (Kennedy, Wilkes, Lane, & Homick, 1985; Turnage, Kennedy, Gilson, Bliss, & Nolan, 1988)

WOFO. The Work and Family Orientation Questionnaire (WOFO, Helmreich & Spence, 1978) is a thirty-two item measure of achievement motivation and attitudes toward family and career. The twenty-three motivational items used in this study form four scales designated Work, Mastery, Competitiveness, and Personal Unconcern. "The first three deal respectively with desire to work hard, desire for intellectual challenge, and desire to succeed in competitive, interpersonal situations. Personal unconcern measures attitudes about the possible negative consequences of achievement and is conceptually related to the notion of Fear of Success" (p. 35). These factors have shown considerable validity in predicting criteria such as college grades, scientific attainment, income, entrepreneurial success, and pilot performance (Carsrud, Olm, & Thomas, 1984; Helmreich, 1982; Helmreich, Spence, Beane, Lucker, & Spence, 1980; Spence & Helmreich, 1983). Reliabilities expressed as Alpha coefficients range from .50 on personal unconcern to .76 and .72 for competitiveness in males and females respectively (Helmreich & Spence, 1978).

VISTECH. The VISTECH 6500 (VCTS 6500), a test of contrast sensitivity, employs three full-sized eye charts which yield five

spatial frequency scores (1.5, 3, 6, 12, and 18 cycles per degree of visual angle). The subject views 3" diameter target gratings (alternating light and dark stripes) from 10 feet with both eyes. There is monotonic gradation in contrast change from 1 to 9 for each of the spatial frequencies gratings. The subject's performance is the total number correct at each frequency and this value is converted via scaled scores which correspond to threshold sensitivity values for each frequency. Contrast Sensitivity Test (CST) measures were selected because they have been shown to correlate with various external criteria of target acquisition (Ginsburg, Easterly, & Evans, 1983; Shinear & Gilead, 1987; Kennedy, Berbaum, Collyer, May & Dunlap, 1988).

ASVAB. A synthetic version (Barron's Educational Series, 1986) of the Armed Services Vocational Aptitude Battery (ASVAB) was used to measure five areas considered to be predictive of tank gunnery performance: 1) General Science, 2) Coding Speed, 3) Automotive and Shop Information, 4) Mechanical Comprehension, and 5) Electronics Information. All ten tests from the full-scale ASVAB were not used because of time constraints in administering the full 2.5 hour test.

Table 1 provides a summary of all the predictor tests, their abbreviations, and a short description of the constructs measured by the test.

Table 1

Summary of Predictor Test Abbreviations and Constructs Measured

ASVAB (Armed Services Vocational Aptitude Battery)

1 - GENERAL SCIENCE - Knowledge of elementary scientific principles.

2 - CODING SPEED - Ability to match key digit string to correct alternative.

3 - AUTO & SHOP INFO - Knowledge of automobile and shop mechanics.

4 - MECHANICAL COMPREHENSION - Knowledge of general mechanical and physical principles.

5 - ELECTRONICS INFORMATION - Knowledge of electrical and radio principles.

WOFO (Work and Family Orientation Questionnaire)

1 - MASTERY - Degree to which person values task mastery.

2 - COMPETITIVENESS - Degree to which a person is competitive.

3 - WORK - Degree to which person values his/her work.

4 - PERSONAL UNCONCERN - Degree to which personal relations interact with task goals.

APTS (Automated Performance Test System)

TAPPING (NPTAP) - Measures manual dexterity (non-preferred hand).

4-CHOICE REACTION TIME (RTARL) - Measure of reaction time.

CODE SUBSTITUTION (CSNC) - Ability to use rules to decode.

GRAMMATICAL REASONING (GRNC) - Measures verbal and grammatical ability.

MANIKIN (MKNC) - Measure of spatial relations.

PATTERN COMPARISON (PCNC) - Measure of spatial relations.

Table 1 (Cont.)

MATH PROCESSING (MPNC) - Measures ability to quickly perform elementary mathematical operations.

TAPPING (TFTAP) - Measures manual dexterity (two hands).

VISTECH - Contrast sensitivity vision test, measuring acuity.

FREQ. 1 - 1.5 Cycles per degree spatial frequency.

FREQ. 2 - 3.0 Cycles per degree spatial frequency.

FREQ. 3 - 6.0 Cycles per degree spatial frequency.

FREQ. 4 - 12.0 Cycles per degree spatial frequency.

FREQ. 5 - 18.0 Cycles per degree spatial frequency.

ISHIHARA - Colorblindness test, measuring ability to detect colors.

Procedure

As shown in Table 2, each training group, composed of 20 randomly assigned subjects, reported for approximately four hours of pretesting (Phase One), eight hours of training and transfer (Phases Two and Three), and two hours of ICOFT testing. Control subjects' procedures were the same, except no VIGS or TOPGUN training was given.

Table 2

Sequence of Orientation, Training, and Transfer for TOPGUN-first and VIGS-first Groups.

Group	Phase 1 (Pretest)	Phase 2 (Training)	Phase 3 (Transfer)	Phase 4 (ICOFT)
TOPGUN First	ASVAB, APTS, WOFO	TOPGUN training (4X27 engagements)	VIGS training (4X27 engagements)	ICOFT
VIGS First	ASVAB, APTS, WOFO	VIGS training (4X27 engagements)	TOPGUN training (4X27 engagements)	ICOFT
CONTROL	ASVAB, APTS, WOFO			ICOFT
Time	4 Hours	2 Hrs/2 Hrs	2 Hrs/2 Hrs	4 Hours

During the first week (Phase 1) of each subject's three week experimentation period, subjects reported to the Institute for Simulation and Training in order to complete the battery of predictor tests that were previously described, plus the Ishihara color blind plates, which provided a screener for color-blindness. They were given standardized instructions and administrative procedures, as described in Appendix I. Testing took approximately four hours. The order of tests was as follows: 1) Ishihara colorblind test, 2) VISTECH contrast sensitivity test, 3) APTS (first replication), 4) ASVAB, 5) APTS (second replication), 6) Work and Family Orientation Questionnaire (WOFO), 7) APTS (third replication), and 8) VISTECH (second replication). Third and fourth VISTECH administrations took place in subsequent sessions.

In Phase 2, twenty subjects were randomly assigned to either one of the experimental groups, TOPGUN-first or VIGS-first, or to the control group, which received only ICOFT training. TOPGUN and VICS subjects completed familiarization and two trials of training on the first day of training. Familiarization on both TOPGUN and VIGS included general information about the device,

instructions concerning how to manipulate the gunnery control handles and switches, and a short scenario (six engagements, representative of each type of target to be encountered). Instructions for TOPGUN, VIGS, and GAS sighting, common to both devices, are included in Appendix J, Appendix K, and Appendix L, respectively. The next day, the same subject completed two more trials of training on the same device, followed by two days training on the alternate device.

TOPGUN training consisted of two 36-target trials per day, each of which took approximately 20 minutes to complete. Table 3 lists a summary of the sequence of engagements presented, representing a cross-section of battle conditions and device settings, including Gunner's Primary Sight and Auxiliary Sight (GPS and GAS) engagements, as well as Thermal Infrared Sighting (TIS) engagements. Target arrays were arranged as indicated in Table 3 so that, within each sight mode, stationary, single targets appeared first; followed by moving, single targets; and, finally, multiple target sets. At the same time, GPS and TIS engagements were presented first (since gunnery behaviors were not expected to vary significantly between these two sight modes), followed by more difficult GAS engagements. Therefore, the total number of TOPGUN engagements presented over the two-day period was 144.

VIGS training consisted of two 41-target trials per day, each of which took approximately 50 minutes to complete. VIGS engagements also presented a cross-section of battle conditions and device settings (see Table 3). Target category sequence was identical to that of TOPGUN; however, due to incompatibility of scenario selection and generation across devices, the number of engagements per target category for VIGS was not exactly the same as for TOPGUN. The total number of VIGS engagements presented over the two-day period was 164.

For both TOPGUN and VIGS training, immediate performance feedback was given by the respective automated performance measurement systems. For example, TOPGUN gave subjects information on length of engagement, number of rounds fired, average rounds per kill, total number of kills, and a cumulative performance score over engagements. For VIGS, information contained time to kill, total trial score, trial performance score and rating (distinguished, superior, qualified, or unqualified), total rounds fired, and elevation and azimuth errors per round. In addition, subjects were given a narrative critique of errors for each trial. In addition, the experimenters corrected performance during trials as necessary, and gave verbal instruction and feedback following trials to promote learning. For example, if the subject consistently forgot to lase, they were reminded to depress the lase button before firing.

Table 3

List of Engagement Sequences Per Device

TOPGUN	VIGS
* Five stationary, single targets (3 GPS, 2 TIS)	* Six stationary, single targets (5 GPS, 1 TIS)
* Five moving, single targets targets (2 GPS, 3 TIS)	* Three moving, single targets (1 GPS, two TIS)
* Five multiple target sets (stationary targets; 3 GPS, 2 TIS)	* Nine multiple target sets (moving and stationary mix; 5 GPS, 4 TIS)
* Four stationary, single targets (GAS)	* One stationary, single target (GAS)
* Four moving, single targets	* Three moving, single (GAS) targets (GAS)
* Four multiple target (moving or stat.) sets (GAS)	* Three multiple target (moving or stat.) sets (GAS)

Note. A multiple target set consists of two targets presented simultaneously.

In Phase 3, all subjects were transported to the GE facilities in Daytona Beach, Florida, for approximately 2.5 hours of familiarization and testing per subject on the ICOFT. Three trained instructor/operators (I/Os) delivered the training using the testing procedures described in Hoffman and Witmer (1989). After familiarization, subjects were required to perform the engagements (10 per exercise) on ICOFT exercises 312110, 313110, 322610, 323210, 332110, and 333110, delivered in standard order. These engagements were selected to match as closely as possible the engagement sequences used on TOPGUN and VIGS trainers. Also, to approximate as closely as possible the engagement sequences used on TOPGUN and VIGS trainers, COAX engagements (a total of four) were deleted from analyses. Immediately upon returning from ICOFT testing, subjects were given an opinion questionnaire which asked questions about both TOPGUN and VIGS trainers (Appendix M).

Performance Measures

When attempting to measure gunnery performance, one may choose from a number of possible indices (i.e., time to fire, time to identify the target, time to kill, round flight time, total time of engagement, and various derived accuracy errors, to

name a few). The performance measures used in this study for VIGS and TOPGUN were azimuth and elevation aiming error (in mils), time to fire (time from presentation of the target to firing the first round), and time to kill. Due to demonstrated low reliability of azimuth and elevation errors (Witmer, 1987), hit percentage was also used as a measure of firing accuracy. Hit percentage was calculated by dividing the number of first rounds hitting the target by the total number of first rounds fired. Finally, composite performance scores, which are part of the computerized records output from each device, were used. For ICOFT, time to fire, time to kill, hit percentage, target acquisition (TA) error, and reticle aim (RA) scores, all part of the session performance summary output, were used.

RESULTS

First, to prepare adequately the data obtained, a complete screening and inspection of the individual scores for each predictor test and simulator performance was completed in order to detect anomalies in the data, such as missing data points (due to equipment malfunction, subject attrition, and data recording error, for example) and "outliers". Based on glitches and/or unreliable data, engagements 2, 22, and 26 were dropped from TOPGUN analyses and engagements 22, 23, 24, and 25 were deleted from VIGS analyses. For TOPGUN, engagement 2 involved a stationary single target engaged using the primary sight, engagement 22 was a stationary single target engaged using the secondary sight, and engagement 26 was a moving single target engaged using the secondary sight. For VIGS, engagements 22 and 23 involved multiple targets (moving and stationary mix) engaged using the primary sight, and engagements 24 and 25 were also multiple targets engaged with thermal sights.

Only first round data were used for all subsequent analyses except for derived scores (e.g., VIGS and TOPGUN performance scores, and ICOFT TA error and RA grade) which may also include second round data, because second round data were incomplete and sporadic. For example, some engagements had no second round, due to the gunner's first round hit. This made analysis of second round data difficult because analysis requires separation of time to fire and time to kill into first round and second round figures. There were many extraneous effects that could occur between round one and round two, such as the obscuration of a target by a tree or the changing of direction by a moving target, making the reliability of round two data extremely dubious. In addition, round two data can be considered unrepresentative in that they are usually present only for more difficult targets (i.e., when there was no first round hit). The scoring difficulties for round two data were further complicated when the second round contained multiple targets. Further advances in each device's performance measurement system output, as well as additional research will be necessary to disentangle the problems

of second round data analysis.

Group means and standard deviations were calculated for each individual test and response measure from all repeated measures (the APTS series, VISTECH charts, and TOPGUN and VIGS simulation scores) to determine the extent of stabilization (Jones, 1980; Jones, Kennedy, & Bittner, 1981) and the slope of learning curves.

Trial Effects on VIGS and TOPGUN

Tables 4 and 5 present the means and standard deviations for each of the TOPGUN and VIGS criterion measures by trial for the TOPGUN-first and VIGS-first groups, respectively. It should be noted that scores for some measures differ across devices, particularly the time to fire and time to kill scores, which are considerably longer for VIGS; the azimuth error scores, which are greater for VIGS; and composite performance scores which are comparatively lower on VIGS. Azimuth and elevation error scores, while recorded as "round point-of-impact" on VIGS, were recorded as "reticle aim" figures on TOPGUN, further contributing to differences. Composite performance scores were also calculated differently for VIGS and TOPGUN. Figures illustrating how the means change for each group across trials are located in Appendix N. For both groups, skill acquisition proceeded at fairly slow but consistent rates with the largest improvements in scores occurring between Trials 1 and 2, as would be expected. At Trial 4 generally means were continuing to improve and deviations were continuing to decrease, indicating that performances had not yet stabilized. In general, more learning was demonstrated within days than across days.

Table 4

Criterion Means and Standard Deviations by Trial and Device for TOPGUN-First Group

Measure		TOPGUN Trials 1	2	3	4	VIGS Trials 1	2	3	4
Time to Fire	(M)	5.00	3.98	3.93	3.74	10.3	10.1	9.98	9.78
	(SD)	1.12	.786	.773	.853	.896	.814	.552	.493
Time to Kill	(M)	5.89	4.93	4.86	4.68	11.2	11.0	10.8	10.6
	(SD)	1.11	.789	.772	.869	.895	.911	.601	.479
Elev. Error	(M)	.495	.480	.461	.448	.444	.402	.417	.364
	(SD)	.089	.057	.054	.062	.099	.071	.053	.055
Az. Error	(M)	.456	.419	.422	.410	1.02	.935	.871	.880
	(SD)	.278	.128	.126	.105	.337	.330	.170	.216
Hit Percent.	(M)	76.5	86.3	86.5	88.6	70.1	76.3	79.0	79.0
	(SD)	11.8	6.91	5.24	5.09	7.61	7.78	8.58	8.12
Perf. Score	(M)	2594	2935	2950	3015	1833	2043	2147	2237
	(SD)	368	194	173	185	250	224	193	170

Table 5

Criterion Means and Standard Deviations by Trial and Device for VIGS-First Group

Measure		VIGS Trials 1	2	3	4	TOPGUN Trials 1	2	3	4
Time to Fire	(M)	11.4	10.4	10.3	9.82	4.20	3.70	3.60	3.41
	(SD)	1.18	.703	.578	.447	.567	.483	.499	.416
Time to Kill	(M)	12.2	11.3	11.2	10.7	5.13	4.63	4.53	4.34
	(SD)	1.17	.692	.542	.443	.560	.487	.499	.420
Elev. Error	(M)	.432	.391	.416	.356	.453	.476	.464	.454
	(SD)	.049	.114	.108	.050	.053	.037	.053	.054
Az. Error	(M)	.949	.907	.918	.842	.378	.377	.350	.348
	(SD)	.205	.252	.241	.252	.129	.086	.107	.090
Hit Percent.	(M)	64.0	71.2	74.4	77.9	84.0	89.3	88.6	90.9
	(SD)	8.27	5.90	8.43	8.37	8.04	7.25	5.88	6.13
Perf. Score	(M)	1686	1958	2029	2147	2860	3037	3035	3087
	(SD)	232	148	197	173	277	215	160	186

The means and standard deviations across the six exercises for ICOFT measures for the total group were as follows: time to fire (M = 16.66, SD = 1.32), time to kill (M = 17.79, SD = 1.51), TA error (M = 2.49, SD = 1.88), RA grade (M = 2.11, SD = .37), and hit percentage (M = 75.10, SD = 12.26).

Stability and Reliability of VIGS, TOPGUN, and ICOFT

Because demonstration of transfer of training between devices requires reliable performance measures, reliabilities for TOPGUN and VIGS criterion measures were estimated by calculating the average intertrial correlation across the four trials for each device (i.e., by averaging all coefficients in the correlation matrix across four trials).

Table 6 presents TOPGUN and VIGS intertrial correlations (i.e., retest reliabilities) and estimated reliabilities (i.e., the average correlation from the complete trial-by-trial matrix) for both groups. The estimated reliability is thus "estimated" not only from correlations of adjacent trials but from correlations between all possible trials to give a more conservative value. Inspection of Table 6 indicates that VIGS performances were consistently less stable and reliable across trials for all six criterion measures, especially when performances were compared between Days 1 and 2 (Trials 2 and 3). This inconsistency in VIGS performance between Days 1 and 2 may be due to differential forgetting of certain engagement or device characteristics among the subjects in the course of the time away from the device. It could also be due to the greater necessity to accommodate to the physical characteristics of the sight or to "warm up" to the physical requirements of the controls.

On the other hand, performance on five of the six criterion measures for TOPGUN showed highly significant stability and reliability. This finding may be related to the relative "ease" of TOPGUN exercises. For example, post test questionnaires indicated that subjects rated TOPGUN as more enjoyable and easier to use without instructor assistance. In addition, the TOPGUN engagements were rated as less difficult than VIGS or ICOFT engagements. Another related explanation for why VIGS reliabilities are consistently lower than those for TOPGUN may be that TOPGUN is more skill-dependent, so that individual differences in skill levels become apparent early and then these differences in subject performances are maintained throughout subsequent sessions. This is reflected in a relatively rigid ordering of individuals with regard to task proficiency.

Table 6

TOPGUN and VIGS Retest Reliabilities and Estimated Reliabilities for Six Criterion Measures

Criterion	Retest Reliability Trial 1-2	Trial 2-3	Trial 3-4	Estimated Reliability
TOPGUN				
Elevation Error	.15	.44*	.37	.29
Azimuth Error	.39*	.73**	.60**	.45**
Time to Fire	.82**	.83**	.81**	.79**
Time to Kill	.84**	.83**	.80**	.78**
Perf. Score	.47**	.62**	.50**	.43**
Hit Percentage	.52**	.58**	.45**	.41**
VIGS				
Elevation Error	.27	.03	.21	.18
Azimuth Error	.69**	-.13	.53**	.18
Time to Fire	.52**	.21	.34	.35
Time to Kill	.50**	.23	.26	.34
Perf. Score	.45*	.33	.52*	.42*
Hit Percentage	.44*	.15	.45*	.27

Note. $N = 39$.
* $p < .01$. ** $p < .001$.

No repeated testing could be accomplished on the ICOFT because of logistical constraints; however, criterion measures were correlated across exercises to determine whether there were consistencies in performances throughout ICOFT training. For the five criterion measures, average estimated reliabilities were .15 for time to fire, .18 for time to kill, .33 for TA error, .33 for RA grade, and .27 for hit percentage. None of these values was statistically significant. This analysis, however, tends to grossly underestimate the true reliabilities. Campshure, Witmer, and Drucker (1990) have devised a more appropriate way to assess the reliability of dependent measures across engagements that differ in difficulty level. However, the Campshure et al. (1990) reliability analysis requires obtaining intercorrelations of each measure across engagements, and ICOFT data in the current study were coded by exercise rather than by engagement. Whether the analysis would be meaningful using such averaged data is questionable. However, the averaged data upon which reliability estimates are based appear in Appendix O.

Relationships Among Criterion Measures for Each Device. Table 7 presents the intercorrelations among criterion measures for the three gunnery trainers for the combined VIGS-first and TOPGUN-first groups (N = 37). The N shrank because of some missing values. The intercorrelations were obtained by first calculating the average score across engagements for each subject and then correlating the averages. For all devices, time to fire and time to kill were highly correlated. However, the high correspondence between speed measures is due to the artifact of using only round one data in the analysis; i.e., if the round failed to kill the target, time to kill was coded as a missing value and therefore was not entered in the correlation matrix. Average elevation and azimuth errors on TOPGUN and VIGS, because they were highly unreliable, did not correlate significantly with any other measures of proficiency, and for that reason such aiming errors were not included as ICOFT measures in favor of the more reliable reticle aim (RA) composite grade. For each of TOPGUN, VIGS, and ICOFT, composite performance scores were highly related to hit percentage scores.

As expected, speed scores were highly related to composite performance scores for TOPGUN and VIGS and to Reticle Aim grades (all in the negative direction) for ICOFT, illustrating the common speed vs. accuracy tradeoff relationship: That is, greater speed is related to greater inaccuracy in target acquisition. Despite these observations, it should be noted that most of the "significant" correlations in Table 7 cannot be interpreted unambiguously in a meaningful way.

Table 7

Intercorrelations Among Criterion Measures for the Three Gunnery Trainers

Criterion	Measure					
TOPGUN	El.Ave.	Az.Ave.	Time Fire	Time Kill	Score	Hit%
Elev. Error	--	.30	-.19	-.20	-.05	-.15
Azim. Error		--	-.25	-.27	-.06	-.07
Time Fire			--	.99**	-.39*	-.18
Time Kill				--	-.38*	-.17
Perf. Score					--	.91**
Hit Percent						--
VIGS	El.Ave.	Az.Ave.	Time Fire	Time Kill	Score	Hit%
Elev. Error	--	-.15	.24	.21	-.37	-.31
Azim. Error		--	.04	.03	-.12	-.21
Time Fire			--	.99**	-.54**	-.28
Time Kill				--	-.50**	-.22
Perf. Score					--	.79**
Hit Percent						--
ICOFT	Time Fire	Time Kill	TA Error	RA Grade	Hit%	
Time Fire	--	.80**	.11	-.49**	.21	
Time Kill		--	.18	-.43*	.07	
TA Error			--	-.77**	-.61**	
RA Grade				--	.47*	
Hit Percent					--	

Note. N = 37.
* $p < .01$. ** $p < .001$.

Cross-correlating Gunnery Performance Across Devices. Because all three devices were designed to train tank gunnery performance, performances measured on one device should be related to performance on the other devices. Table 8 shows correlations between various averaged measures of gunnery performance on TOPGUN, VIGS, and ICOFT. Positive correlations do not demonstrate a causal link between performances, but do suggest that common skills or abilities are required for proficiency. There were no significant correlations between TOPGUN and VIGS. This may be a function of lack of criterion reliability in one or both of the devices. TOPGUN speed measures (time to fire, time to kill) correlated significantly with similar ICOFT measures, but accuracy measures (hit percent, performance scores) showed no significant correlations. Time to fire was also significantly correlated between VIGS and ICOFT, but to a lesser degree, suggesting that the two devices may measure a common ability. Thus, TOPGUN and VIGS may predict speed

on ICOFT with TOPGUN possibly yielding better predictions. On the other hand, VIGS performance scores were highly related to similar ICOFT composite measures (target acquisition, reticle aim). In addition, the time to fire scores for VIGS and ICOFT were significantly correlated. Again, it is not surprising that high correlations between VIGS and ICOFT were found for performance scores because the performance score is the only score which demonstrated reliability for VIGS. Because ICOFT elevation and azimuth errors were not used, hit percentage is the best accuracy measure available on ICOFT. However, the .08 correlation between hit percentage on VIGS and ICOFT suggests no relationship between accuracy on the two devices.

Similar cross-correlations were also performed between criterion measures of each device by trial to determine whether practice would increase the size of the inter-device correlations. There were no significant correlations on Trial 1. TOPGUN and ICOFT speed measures started to correlate on Trials 2 (fire r = .56, kill r = .53) and 3 (fire r = .60, kill r = .53) and remained significant on Trial 4 (fire r = .48, kill r = .41). VIGS and ICOFT speed measures did not correlate significantly until Trial 4 (fire r = .46, kill r = .44), so that by Trial 4, all speed scores were significantly correlated, ranging from .41 to .48. The VIGS performance score also correlated significantly on Trial 3 with ICOFT target acquisition (TA) error (r = -.40) and reticle aim (RA) grade (r = .42). In addition, the VIGS performance score correlations with ICOFT TA and RA scores increased to -.48 and .46 on Trial 4, respectively. These data suggest that four trials (108 engagements per device) may not be sufficient to demonstrate true relationship between devices.

Table 8

Cross-Correlations of Criterion Measures Between the Three Gunnery Trainers

Criterion	TG/VIGS	TG/ICOFT	VIGS/ICOFT
Elevation Error	-.1696		
Azimuth Error	.0997		
Time to Fire	.3697	.5331**	.3848*
Time to Kill	.3769	.4734*	.2916
Hit Percentage	.0446	.3825	.0795
Performance	.2853	-.1438 (TA)	-.5139** (TA)
Scores		.3053 (RA)	-.5552** (RA)

Note. N = 37.
* p < .01. ** p < .001.

Transfer of Training

Analysis of variance is preferred to correlation as a method to demonstrate transfer. To determine jointly whether learning occurred during TOPGUN and VIGS training (trial effect) and whether performance on one device transferred to the other (group effect), analyses of variance was applied to six performance criteria common to TOPGUN and VIGS. Table 9 presents results of the analysis of variance (ANOVA). Significant main effects were found for Group and Trial on both speed measures (time to fire, time to kill) and two accuracy measures (hit percentage, performance score) for both TOPGUN and VIGS. In all cases, the group which had received prior training on the alternate device performed better. Average elevation and azimuth errors were too erratic to produce consistent or interpretable results. No interactions were statistically significant.

Table 9

Analyses of Variance for TOPGUN and VIGS Criteria by Group and by Trial

Device/Criterion	F-Ratios for ANOVA Group	Trial	Group X Trial
TOPGUN			
Time to Fire	14.38**	15.25**	1.12
Time to Kill	14.16**	14.36**	.96
Elevation Error	.81	1.61	1.34
Azimuth Error	7.83*	.54	.12
Hit Percentage	10.30*	12.61**	1.21
Performance Score	12.96**	15.49**	1.53
VIGS			
Time to Fire	15.45**	15.55**	3.26
Time to Kill	13.61**	13.53**	2.91
Elevation Error	.39	7.03**	.04
Azimuth Error	.35	1.76	.40
Hit Percentage	11.35**	16.05**	.76
Performance Score	11.93**	33.39**	.20

Note. Group df = 1, Trial df = 3, Total df = 159.
* $p < .01$. ** $p < .001$.

Transfer of Training from VIGS and TOPGUN to ICOFT. Table 10 presents ANOVA summaries comparing control, TOPGUN-first, and VIGS-first groups on their ICOFT performances, and contrasts were performed to determine if groups differed significantly in performance. Groups did not differ on time to fire or time to kill speed measures. However, the experimental groups significantly outperformed the control group on all other criterion measures. Inspection of means indicates that there was no perceptible difference between the TOPGUN-first or VIGS-first

groups except for the TA error measure, where the TOPGUN-first group performed significantly better than the VIGS-first group.

However, when we determined transfer using Trial 4 data only for TOPGUN-First and VIGS-First groups and ICOFT scores as dependent measures, we found that the TOPGUN-First group was superior for TA error ($F = 6.18$, $df = 1,36$, $p < .02$) and RA grade ($F = 5.54$, $df = 1,36$, $p < .02$). The mean TA score for TOPGUN-First vs. VIGS-First was 1.50 vs. 3.78, and for RA score was 1.75 vs. 1.39, respectively. Thus, with as few as four sessions practice, TOPGUN-First subjects are superior in terms of transfer to ICOFT composite measures. In addition, the TOPGUN-First group demonstrated faster performance scores on time to fire (TOPGUN = 15.69, VIGS = 16.00) and time to kill (TOPGUN = 16.90, VIGS = 18.59) criteria and higher hit percentage (TOPGUN = 29.80, VIGS = 25.69) scores, although these differences were not statistically significant. Whether TOPGUN would be superior to VIGS when used alone before transfer to ICOFT cannot be determined because of the interpolated practice on the alternate device.

Table 10

Means, Standard Deviations and One-way Analysis of Variance of ICOFT Criterion Measures by Group

Group Means and Standard Deviations (in parentheses)

Criterion	Control	TOPGUN-First	VIGS-First	F (df =2,56)
Time to Fire	17.19 (1.44)	16.41 (1.23)	16.36 (1.15)	2.50
Time to Kill	18.23 (1.95)	17.61 (1.29)	17.52 (1.15)	1.25
TA Error	3.81 (2.36)	1.60 (0.77)	2.07 (1.40)	9.65**
RA Grade	1.84 (0.82)	2.24 (0.30)	2.24 (0.38)	9.79**
Hit Percentage	65.20 (11.36)	80.59 (8.96)	79.44 (10.18)	13.51**

Note. Control N = 19, TOPGUN-First N = 20, VIGS-First N = 18.
** $p < .001$.

Predicting Performance on Tank Gunnery Simulation Devices

As discussed earlier, the prediction of complex performances, such as those involved in tank gunnery, depends on finding tests that are stable and reliable.

Differential Stability and Reliability of Predictors. Differential stability has been described as the determination of the number of trials that are needed for the trial-to-trial intercorrelations to stabilize. It represents the point at which there is stable relative ordering of individuals over repeated testings. Inspection of the trial-to-trial intercorrelations and estimation of the "trial of stability" for each test's performance measures has implications for the stability and potential reliability of those measures (Jones, 1980; Jones et al., 1981). Therefore, trial-to- trial intercorrelations were obtained for all repeated measures. An estimate of stability is given by taking the average of all correlations in a trial-to-trial correlation matrix, following the trial at which intertrial correlations plateau.

Table 11 presents the overall means and standard deviations, retest reliabilities, and the estimated reliabilities for the APTS tests across trials. "Estimated reliability", one index of differential stability, is the average of <u>all</u> correlations in the intertrial correlation matrix, not just the off-diagonals which give information about test-retest reliability. As shown in Table 11, all APTS tests were highly reliable, with all except Math Processing and Four-Choice Reaction Time having estimated reliability correlations greater than .707, the value at which 50% of the variance is explained. In addition, but relatedly, all means and standard deviations stabilized early. Stability of means and standard deviations is determined subjectively by determining at what trial values start to plateau; the estimated trial of stability is then checked by a second analyst, and, where there are disagreements, a consensus is reached (Turnage, Kennedy, & Osteen, 1987).

Table 11

Overall Means and Standard Deviations, Retest and Estimated Reliabilities for APTS Scores Across Trials

Test	Mean	SD	Retest Reliability Trial 1-2	Retest Reliability Trial 2-3	Estimated Reliability
NPTAP	32.98	8.93	.76	.88	.76
THTAP	36.65	7.22	.80	.77	.76
RTARL	.48	.09	.90	.93	.92
CSNC	52.32	8.19	.75	.76	.73
CSARL	2.07	.31	.76	.74	.73
GR	27.51	6.93	.65	.77	.68
GRARL	3.53	.85	.69	.81	.71
MKNC	60.55	11.04	.85	.86	.83
MKARL	1.66	.39	.89	.89	.86
PCNC	84.55	12.15	.85	.84	.84
PCARL	1.04	.22	.87	.85	.84
MPNC	31.76	7.58	.70	.66	.67
MPARL	1.11	.11	.67	.66	.61

<u>Note</u>. N = 59. All significant at $p < .001$.

Table 12 presents the intertrial (retest and estimated) reliabilities for the five contrast sensitivity frequencies of VISTECH charts, summed across the three charts. The very high reliabilities, particularly the higher spatial frequencies, corroborate recent work by Kennedy (1989), which found that VISTECH measures of contrast acuity taken repeatedly (15 trials) achieved temporal stability after only one administration.

Table 12

Retest and Estimated Reliabilities for Five Contrast Sensitivity Frequencies

Spatial Freq	Retest Reliability Trial 1-2	Trial 2-3	Trial 3-4	Estimated Reliability
FREQ1 (1.5 Cycles)	.60	.51	.50	.51
FREQ2 (3 Cycles)	.84	.70	.75	.68
FREQ3 (6 Cycles)	.84	.70	.75	.68
FREQ4 (12 Cycles)	.86	.80	.86	.80
FREQ5 (18 Cycles)	.88	.74	.88	.82

Note. N = 59. All significant at $p < .001$.

The means, standard deviations, and intertest correlations of ASVAB and WOFO scores are presented in Table 13. ASVAB scores for the student subject population used in this study were similar to actual ASVAB norms for the tank gunner MOS (Grafton, personal communication, 1989). The mean norms for the 1980 ASVAB test scores, which were the latest data available from the U.S. Army Research Institute, were: General Science, 16; Coding Speed, 48; Mechanical Comprehension, 14; Electronics Information, 11.5; and Auto and Shop Information, 14.5. Inspection of Table 13 also reveals that ASVAB tests 1,3,4,and 5 were positively correlated, possibly indicative of a common intelligence (or G) factor, and were negatively correlated with coding speed (ASVAB 2). All WOFO achievement motivation scores were highly correlated.

Table 13

Means, Standard Deviations, and Intertest Correlations of ASVAB and WOFO Predictor Scores

Predictor	Mean	SD	Intercorrelations				
ASVAB			ASVAB1	ASVAB2	ASVAB3	ASVAB4	ASVAB5
1-Gen. Science	15.67	3.58	--	-.09	.31*	.27	.53**
2-Coding Speed	48.43	11.57		--	-.14	-.05	-.03
3-A&S Info.	14.57	3.02			--	.56**	.48**
4-Mech. Comp.	13.18	3.80				--	.51**
5-Elec. Info.	9.05	2.69					--
WOFO			WOFO1	WOFO2	WOFO3	WOFO4	
1-Mastery	2.18	2.10	--	.56**	.46**	.44**	
2-Work	3.97	1.60		--	.42**	.46**	
3-Competition	1.53	1.61			--	.30	
4-Pers. Unc.	1.18	1.00				--	

Note. N = 60.
* $p < .01$. ** $p < .001$.

Table 14 presents the intertest correlations for APTS and VISTECH predictors, based on scores summed over three trials for APTS and four trials for VISTECH. Average response latency scores for APTS tests were dropped from this and further analyses because past research (Turnage, Kennedy, & Osteen, 1987) has indicated correlations between number correct and latency measures to exceed .90, indicating that use of both scores would be redundant. Several APTS tests (e.g., Manikin, Grammatical Reasoning) showed high correlations with other tests, and all VISTECH scores were highly intercorrelated. In general, while intertest correlations within the four predictor sets was moderately high, there appeared not to be sufficient reason to discard or combine any scores from the predictor sets for further analyses because we were interested in retaining as many potential predictors as possible at this stage of analysis.

Table 14

Intertest Correlations for APTS and VISTECH Predictors, Summed Across Trials

Predictor	Intercorrelations							
<u>APTS</u>	NPTAP	TPTAP	RTARL	CSNC	GRNC	PCNC	MKNC	MPNC
NPTAP	--	.51**	-.19	.11	.09	-.04	.02	.02
TFTAP		--	-.17	.21	.24	.04	-.07	-.12
RTARL			--	-.34*	-.34*	-.28	-.52**	-.30
CSNC				--	.38*	.44**	.53**	.54**
GRNC					--	.39*	.52**	.20
PCNC						--	.56**	.43**
MKNC							--	.53**
<u>VISTECH</u>	FREQ1	FREQ2	FREQ3	FREQ4	FREQ5			
FREQ1	--	.83**	.66**	.51**	.46**			
FREQ2		--	.80**	.65**	.59**			
FREQ3			--	.91**	.81**			
FREQ4				--	.90**			
FREQ5					--			

Note. N = 59.
* $p < .01$. ** $p < .001$.

Cross-Task Correlations Among Predictor Scores

To determine the degree to which individual tests from all predictor batteries shared common variance, a cross-task intercorrelation matrix was constructed. There were very few significant correlations, the only ones being VISTECH frequencies 1 and 2 with Math Processing (.31 and .32, respectively), VISTECH Frequency 4 with WOFO Mastery (.31), ASVAB General Science with WOFO Work (-.44), and ASVAB Coding Speed with APTS Code Substitution (.40) and Manikin (.38). These results indicate that predictor sets were relatively independent.

Correlations and Regressions of Predictors with Criterion Scores

To determine whether biographical variables, APTS, ASVAB, VISTECH, and WOFO scores would predict gunnery performance measures, all predictors were correlated with all criterion scores for Groups 1 and 2 combined ($N = 37$). Of the biographical variables, only two related significantly to any criterion performance: Time in ROTC was negatively correlated ($r = -.50$, $p < .001$) with ICOFT hit percent scores. There is no apparent reason for this relationship. Time spent playing video games was positively correlated ($r = .45$, $p < .01$) with APTS reaction time, a not unexpected finding.

The other predictor scores were correlated by group to the respective criterion performances, where criteria were summed across trials for TOPGUN and VIGS measures. The TOPGUN-first group contained 19 subjects, the VIGS-first group contained 18 subjects, and the control group contained 18 subjects, because of some shrinkage due to missing data. Thus for each group, 5 VISTECH, 5 ASVAB, 8 APTS, and 4 WOFO scores were used to predict either 5 or 6 criterion scores, based upon the reference group. There were few significant correlations, probably due at least in part to small sample sizes. However, when the groups were combined ($N = 37$), there were statistically significant ($p < .01$) correlations between ASVAB mechanical comprehension scores and VIGS performance scores (for VIGS time to fire, $r = -.39$, for performance score, $r = .49$, and for hit percentage, $r = .42$); between VISTECH contrast sensitivity (FREQ1) and TOPGUN and ICOFT scores (for TOPGUN time to fire and time to kill, $r = -.41$ and $-.40$, respectively, and for ICOFT time to kill, $r = -.40$); between both APTS tapping tests and VIGS time to fire and time to kill (all r's = .42); between various APTS scores (4-Choice Reaction Time, Code Substitution, Math Processing) and VIGS and ICOFT composite accuracy scores (reaction time $r = -.42$ with VIGS performance score and $r = -.40$ with VIGS hit percentage, code substitution $r = .39$ with VIGS performance score, and math processing $r = .41$ with ICOFT target acquisition score); and between the WOFO personal unconcern score and the TOPGUN performance score ($r = -.38$).

A common procedure used to correct for inherent unreliability of variables is Spearman's (1904) correction for attenuation formula, which utilizes estimated reliabilities of both predictor and criterion variables to project "true" correlations. Using estimated reliabilities for TOPGUN and VIGS (Table 6), VISTECH (Table 12), and APTS (Table 11), the above correlations were corrected as follows: VISTECH FREQ1 with TOPGUN time to fire and kill, $r = -.65$ and $-.63$, respectively; TFTAP with VIGS time to fire and kill, $r = .81$ and $.83$, respectively; NPTAP with VIGS time to fire and kill, $r = .81$ and $.83$, respectively; 4-Choice Reaction Time with VIGS performance score and hit percentage, $r = -.68$ and $-.80$, respectively; and Code Substitution number correct with VIGS performance score, $r = .70$. This correction indicates the true relation between variables if the predictor and criterion variables were perfectly reliable.

Although it would have been possible to find more potential predictors of ICOFT by using all data for all three groups, when this analysis was performed ($N = 56$), the only meaningful ICOFT predictor was APTS Four-Choice Reaction Time, which was significantly correlated with ICOFT time to fire ($r = .34$, $p < .01$), TA error ($r = .67$, $p < .001$), and RA grade ($r = -.38$, $p < .01$).

To determine the significant predictors of trainee performances for the three gunnery trainers, multiple regressions were run using the 22 predictors as independent variables and each criterion measure as dependent variables. The stepwise selection method was used. Stepwise selection is a combination of backward and forward procedures, where the first variable selected is the independent variable with the highest correlation, the second is that with the highest partial correlation, etc. When variables can no longer meet the PIN = .05 entry requirement (i.e., they increase the F value at least .05), then the backward elimination procedure takes over to remove variables in the equation that fail to meet the POUT = .10 removal criterion (i.e., they decrease the F value at least .10). The results are summarized in Table 15. Although it is recognized that the expected value of R equals 1.00 when the number of independent variables equals the number of subjects, there were several reasons for using the large predictor set. First, each predictor set was selected because previous research had shown relations between predictors and criteria; thus, this was not a "shotgun" approach. Second, although some predictor sets, especially VISTECH scores, demonstrated high internal correlations, there were no clear reasons to develop composite scores when the multiple regression process would automatically exclude highly correlated scores. Last, and perhaps most importantly, the use of three distinct groups allows one to compare whether criterion variance is explained by the same predictors across devices, thus providing a powerful form of cross-validation.

Table 15

Summary of Number of Significant Predictors from Stepwise Regression of All Predictors (22) with Criteria from Three Training Devices

	ICOFT			TOPGUN		VIGS	
Predictor	Total Sample (N=55)	Control (N=17)	Exp. Group (N=37)	TOPGUN-First (N=18)	Exp. Group (N=38)	VIGS-First (N=19)	Exp. Group (N=39)
ASVAB1				1		2	
ASVAB2					1		
ASVAB3	2	3	2		2	1	
ASVAB4						1	2
ASVAB5	1						
WOFO1							
WOFO2						4	
WOFO3						1	
WOFO4					1		
FREQ1			1				
FREQ2			1				
FREQ3						1	
FREQ4		1					
FREQ5							
NPTAP		1					
TFTAP							
CSNC	1		1			1	4
PCNC	1	2				2	
GRNC							1
MKNC						2	
MPNC			1				
RTARL	3	2	1			2	

Note. Full predictor labels appear in Table 1.

Table 15, which lists significant predictors of all criteria from the three devices, indicates that there were few significant predictors, in line with the results that were found when each predictor was individually correlated with each criterion. The first three columns show that there were only 8 statistically significant predictors of ICOFT criteria using the total sample (N = 56), 9 using the control group only (N = 17), and 7 using both experimental groups (N = 37). Only 1 predictor was statistically significant for TOPGUN criteria using the TOPGUN-First group, and 4 were using the two experimental groups. On the other hand, 17 predictors showed statistically significant relations with VIGS criteria for the VIGS-First group, and 7 were significant for the total experimental group. In most regressions, the multiple R failed to exceed .707, which when squared, signifies that 50% of the criterion variance has sufficiently been accounted for by the predictors. Exceptions were: 1) ICOFT TA error predicted by RTARL, ASVAB3, ASVAB5 (R = .75), and ICOFT time to fire predicted by PCNC and FREQ4 (R = .84) for the total sample; 2) ICOFT TA error predicted by RTARL, ASVAB3 (R = .94), and ICOFT RA grade predicted by RTARL, PCNC, ASVAB3 (R = .88) for the control group; and 3) VIGS time to fire predicted by WOFO2, MKNC, RTARL, PCNC, ASVAB1, FREQ3 (R = .95), VIGS time to kill predicted by MKNC, WOFO2, RTARL, PCNC, ASVAB1, WOFO3 (R = .96), and VIGS performance score predicted by CSNC, WOFO2, ASVAB3 (R = .76) for the VIGS-first group.

Inspection of the "patterns" of significant predictors suggested using a reduced set of predictors for each device to conform to the ratio of one predictor for every 10 subjects that is more acceptable for regression research than the previous analysis in which the number of predictors equalled, or even exceeded, the number of subjects in some cases. ASVAB3, PCNC, and RTARL were selected to predict all ICOFT criteria; ASVAB2 and 3, WOFO4, and FREQ1 were chosen for TOPGUN criteria; and WOFO2, CSNC, MKNC, and RTARL were selected for VIGS criteria. Stepwise regressions were then run on the total ICOFT group (N = 55) and the total experimental group (N = 38) for TOPGUN and VIGS criteria. Results are reported in Table 16. It can be seen that none of the multiple correlations was exceptionally high, as only 9 prediction equations achieved statistical significance over all training criteria. When the adjusted R^2 is applied to reflect how well the model fits the population, the results are further diminished in value. Although there were some suggestions about skills that may underlie performances on each device, interpretations based on these data would need to be cautious. However, it would appear that contrast sensitivity, coding speed, and some knowledge of specific mechanical principles predicts TOPGUN performance. It is curious that WOFO4, which measures attitudes about the possible negative consequences of achievement (i.e., fear of success) was positively related to the TOPGUN performance score. Code Substitution, which involves cognitive and perceptual processing featuring rapid visual search encoding

and decoding, appears to predict VIGS performance. ICOFT performance, on the other hand, appears to be primarily predicted by response speed and knowledge of mechanical principles, at least in early learning stages as represented in this study. Thus, because performance on different devices is predicted by different predictors, it may be that there are fundamental differences in the designs of these devices or the sensitivity of their performance measurement systems to diverse operator inputs.

Table 16

Summary of Significant Predictors of Trainee Performances for the Three Trainers Using Reduced Set of Predictors

Trainer/Criterion	Significant Predictor(s)	R	R^2	Adj.R^2
TOPGUN (N = 38)				
Time to Fire	FREQ1	.43*	.19	.16
Time to Kill	FREQ1	.34*	.12	.10
Perf. Score	WOFO4, ASVAB2, ASVAB3	.59**	.35	.30
VIGS (N = 39)				
Perf. Score	CSNC	.49**	.24	.22
Hit Percentage	CSNC	.41*	.17	.15
ICOFT (N = 55)				
Time to Fire	RTARL	.34*	.12	.10
TA Error	RTARL, ASVAB3	.72**	.52	.50
RA Grade	RTARL	.38*	.15	.13
Hit Percentage	RTARL, ASVAB3, PCNC	.49*	.24	.20

Note. * $p < .01$. ** $p < .001$.

Finally, an analysis was performed of the subject opinion questionnaires which were administered immediately after ICOFT testing. The mean responses for TOPGUN and VIGS questions are presented in Tables 17 and 18. In general, subjects enjoyed training on both devices and thought the devices helped them to improve or learn tank gunnery skills. Subjects experienced more difficulty with VIGS than TOPGUN, but were fairly evenly divided as to which device they would use to train on if given a choice. They were somewhat equally in agreement with the statement that skills trained on TOPGUN (VIGS) were the same as on ICOFT, but there was a good deal of variability in responses. There was equally strong support for the effectiveness of prior TOPGUN and VIGS training in helping performance on ICOFT. Specific comments regarding each device may be found in Appendix P.

Table 17

Mean Rating Scale Values for TOPGUN Questionnaire Items

TOPGUN Items	MEAN	SD
1. I enjoyed training on the TOPGUN device.	4.7	.71
2. TOPGUN helped me to improve/learn tank gunnery skills.	4.2	.74
3. If I could see the target, I could hit it.	4.2	.78
4. Most of the target engagements were too difficult.	1.8	1.0
5. If given a choice, I would use the TOPGUN to train on.	3.2	1.2
6. I could use TOPGUN without any instructor assistance.	3.9	2.3
7. I thought TOPGUN engagements were too easy.	3.4	.87
8. I had trouble finding targets on TOPGUN.	1.9	1.0
9. I liked the "unity window" for locating targets.	3.4	1.2
10. The skills trained on TOPGUN were the same as on ICOFT.	3.6	1.3
11. The device features on TOPGUN (color coding of targets, etc.) were helpful when learning to hit the targets.	3.7	.89
12. Prior TOPGUN training helped my performance on ICOFT.	4.4	.77

Note. Rating scale values: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree.

Table 18

Mean Rating Scale Values for VIGS Questionnaire Items

VIGS Items	Mean	SD
1. I enjoyed training on the VIGS device.	4.4	1.0
2. VIGS helped me to learn/improve my gunnery skills.	4.4	.84
3. If I could see the target, I could hit it.	3.7	1.0
4. Most of the engagements were too difficult.	2.2	.96
5. If given a choice, I would choose the VIGS to train on.	3.4	1.3
6. I could use VIGS without any instructor assistance.	2.7	1.2
7. I thought the VIGS engagements were too easy.	2.8	1.0
8. I had trouble finding targets on VIGS.	2.2	.84
9. I was confused by the adjustments required by VIGS.	2.3	1.3
10. The skills trained on VIGS were the same as on ICOFT.	3.5	1.4
11. The voice on VIGS was difficult to understand.	2.8	1.3
12. Prior VIGS training helped my performance on ICOFT.	4.4	.87

Note. Rating scale values: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree.

DISCUSSION

The purpose of this study was to investigate whether training transfer occurred between two part-task gunnery trainers, TOPGUN and VIGS, and performance on a high-fidelity trainer, ICOFT. With respect to our original research questions regarding transfer, we found that: 1) performance improved at equal rates during TOPGUN and VIGS training; 2) there was significant transfer between most TOPGUN and VIGS performances with no apparent superiority of either device; 3) except for speed measures, TOPGUN and VIGS training transferred to ICOFT, and 4) there was no apparent difference between the TOPGUN-VIGS or VIGS-TOPGUN sequences of training. Although there is no clear reason why accuracy but not speed should transfer, a likely explanation would be the nature of the instructions and feedback, which stressed hits more than speed. Practice on devices does seem to engender a pronounced desire to hit the target, and target hits are more directly reinforced by the subject seeing the target disappear, by having the TC pronounce "cease fire", and by providing the subject with immediate performance feedback. Although speed measures influence performance scores, their influence on gunnery proficiency is not so visible or apparent.

Witmer (1988) found no significant transfer between VIGS and UCOFT as we did. Differences in results are probably a function of having more trials of VIGS practice in this study, as well as hardware differences between the VIGS used in Witmer's study (manufactured by Perceptronics) and the VIGS used in this study (manufactured by E.C.C.). These results are also generally consistent with past research (e.g., Witmer, 1988) that demonstrated instability of elevation and azimuth errors, and performance improvement as a function of practice. However, Witmer found significant correlations between VIGS and UCOFT on hit percentage and elevation aiming error measures, whereas we found significant correlations for time to fire and kill measures and composite performance measures but not for hit percentage. This could be due to the fact that hit percentage was calculated differently by Witmer.

In comparing our data to preliminary data reported by Hagman (1989, personal communication) who studied training transfer between TOPGUN and COFT, we found evidence for transfer over all exercises from TOPGUN to COFT (especially for Trial 4 data) whereas Hagman found transfer for stationary targets only. An analysis has been conducted to discern whether transfer occurs differentially for engagements featuring 1) stationary vs. moving targets, 2) single vs. multiple targets, and 3) GPS, GAS, and TIS sightings for both TOPGUN and VIGS devices (Bliss, 1989).

Evidence of transfer in this study can in part be attributed to adherence to Boldovici's (1987) guidelines, enumerated in the introduction, for reduction of sources of error in transfer

experiments with military training devices. For example, comparison groups contained 19 or 20 subjects each, subjects were randomly assigned to groups, and groups were treated similarly except for treatments under investigation. For example, data collection was completely standardized by the use of prerecorded and carefully written instructions, the requirement for subjects to be tested at exactly specified times, and the automated recording of most output data. Human-coded data were checked and double-checked when recorded and when entered onto computer discs. Likewise, data analysis was only begun after a thorough inspection of scores to spot errors; and in several cases simulator glitches and errors led to elimination of faulty data. These procedures are necessary to produce a "clean" data set on which to base analyses and are an integral part of establishing test reliability. On the other hand, certain faults, which were found in TOPGUN and VIGS presentations and in coding of data, added to unreliability of data (see Appendix P).

In addition, we attempted to provide adequate practice to affect proficiency. However, we found that with the exception of speed scores, performances on VIGS were still improving at Trial 4. Had performances been allowed to stabilize, it is expected that more transfer would have been demonstrated. This point also relates to Boldovici's fifth point, that measurement of the criterion task should be reliable. In this study, both VIGS and ICOFT measures had questionable reliabilities; for VIGS this was empirically assessed, and for ICOFT it would have to be presumed because of subject inexperience, the relative complexity of the device and engagements, and the use of only one trial. It is possible the hypotheses regarding what predictors are related to the criteria on various devices are correct. However, they may not appear to receive support because of statistical imperfections. This argument will be developed later.

Boldovici's point that inappropriate analyses are often used to estimate transfer is in line with our data analysis approach, where we opted for a parsimonious ANOVA approach to estimate transfer. We had hoped to use raw score values wherever possible to express transfer because raw scores usually carry greater precision of meaning (cf. Gagne et al., 1948). However, because of unreliable raw scores such as elevation and azimuth aiming errors, we used a number of composite measures. An irony is that while composite scores ordinarily possess greater validity, their reliabilities are difficult to gauge. A composite score combines many <u>different</u> elemental skills which may themselves be uncorrelated with each other. Although composite scores tend to "spread out" the criterion and thus permit the possibility of greater statistical reliability, their use opens the door for potential interpretation problems regarding the transfer of <u>specific</u> skills between devices by being based on such diverse elements.

The secondary purpose of this study was to determine whether various perceptual, cognitive, psychomotor, and motivational variables would predict performance on three tank gunnery simulators, of varying degrees of fidelity to the M1 tank. We believed that more valid predictors could be surfaced because of careful selection of subjects, rigorous control of data collection, and focussed emphasis on determining the reliability and task-relatedness of all measures.

Our premise that reliability and stability of measurement would by required to demonstrate validity adequately was supported. APTS measures stabilized rapidly and exhibited average reliabilities above .76. VISTECH measures likewise stabilized rapidly and were extremely reliable (average r=.71). TOPGUN performance measures, with the exception of average elevation error, were quite stable and reliable. This finding is probably due to the fact that engagements are very easy, and there is a very liberal "kill zone". VIGS performance, on the other hand, never stabilized over four trials. Indeed, retest performances were more highly related on the first two trials than later in practice, and there was very little carryover between the two days of practice. Partially because of their high reliabilities, APTS Code Substitution, Four-Choice Reaction Time, and Pattern Comparison; FREQ1; and ASVAB scores proved to be the best overall predictors of gunnery performance despite generally low multiple correlations.

However, it is not enough to use reliability as the sole explanation for significant predictor-criterion relationships because, as noted before, there should be important task- and skill-related underpinnings to these findings. In this study, for example, it would be helpful to be able to determine the extent to which trainable skills and tasks, as defined by Hoffman and Morrison (1988, see Appendices A,B,C,D), transferred across devices. However, it was not possible to break down gunnery activities into broad categories (such as PREOPS checks, PREFIRE checks, acquiring targets, etc.) within the global scope of the performance measures used in this study. This fact also precluded an examination of fidelity issues inherent in training system design (cf., Hays & Singer, 1989) which would also suggest an optimal VIGS, TOPGUN, COFT mix.

What is apparent from this study, as with those that have gone before (e.g., Graham, 1986), is that predictive validities of both ability and nonability tests as well as devices themselves are attenuated due to criterion unreliability. For example, applying the correction for attenuation formula (Spearman, 1904) to the significant .43 predictive validity coefficient between nonpreferred tapping (reliability = .76) and VIGS time to kill (reliability = .78) increases the true relationship to .83. Applying the formula to the nonsignificant .33 validity coefficient between contrast sensitivity FREQ1 (.51)

and the TOPGUN performance score, which shows moderately high reliability (.43), increases the validity value to .47. Also, applying the formula to the .21 validity coefficient between math processing (reliability = .67) and VIGS hit percentage (reliability = .27) increases the validity to .49.

The upper limit for predictive validity is the geometric mean of the criterion reliability and the predictor reliability (Kendall & Stuart, 1977). This means that when criteria have low reliabilities (e.g., less than .55), the highest possible relationship between a predictor and a criterion is less than .74, and this result would require that the predictor have near perfect reliability and that the predictor and criterion totally overlap. Also, if another factor (e.g., motivation, cognitive ability, or perceptual speed) were also related to the criterion in a unique way from the first predictor, the best possible value for r = .74 would be lowered accordingly. Based on rational expectations of reliabilities, studies have been conducted with insufficient sample sizes to reveal a statistically significant difference. The correlation magnitude which is required for statistical significance for a sample size of 20, for example, would need to be .423 at p = .05 or .537 at p = .01, values which are rarely attainable in studies of tank gunnery devices. This notion of statistical power has been discussed by Morrison (1988) who analyzed differences between group means in tank gunnery research and concluded that statistical comparisons of company-sized crews (N = 14) are relatively insensitive to mean differences in speed and accuracy of performance.

One of the major reasons that we found significant transfer across devices in this study was because repeated-measures were used. Repeated testing serves to increase statistical power, often by increasing reliability. In this study, only one administration of ICOFT was possible; thus, it is presumed that ICOFT performances were not extremely stable or reliable, even though transfer was demonstrated.

In summary, our results indicate that there is evidence for positive skill transfer between TOPGUN, VIGS, and COFT training devices. The statistical significance of predictive validities and transfer between both outside predictors and devices is a function of time-on-task and measurement reliability. As future research incorporates the necessity to increase performance stability through sufficient practice on devices and to improve measurement reliability through careful attention to sources of measurement error, so too will it become possible to identify the critical tank gunnery skills that enhance gunner selection and training.

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APPENDIX A

Breakdown of TOPGUN Activities and Evaluation of Trainability*

BROAD CATEGORY	ACTIVITIES TRAINABLE
1. PREOPS CHECKS	Check Power Control Handles (YES)
2. PREFIRE CHECKS	Report Weapon Status (YES) Receive TC Briefing (YES)
3. ACQUIRE TARGETS	Select GPS/TIS Magnification (YES) Search on Gun Axis With GPS (YES) Alternate Using GPS with TIS (NO)+ Execute Search Techniques (NO) Search on Gun Axis with TIS (YES) Detect Targets/Signatures/ Obstacles (NO) Locate Targets (YES) Announce GUNNER REPORT (NO) Estimate Range to Evaluate LRF Return (YES)
4. ENGAGE SINGLE TARGETS WITH MAIN GUN	Thermal Magnification (YES) Thermal Mode: ON (YES) Evaluate Range Display (YES) Check Ready to Fire Faults (NO) Listen for "UP" (YES) Listen for "FIRE" (NO)+ LRF: Arm Last RTN (NO)+ GPS:3x (YES) Gun Select:MAIN (NO) Sight Through GPS (NO) Grasp Palm Switches (YES) Announce "IDENTIFIED" (YES) Switch GPS to 10x (YES) Lay on Target Center of Mass (YES) Track Moving Target (YES) Depress Lase Button (YES)
5. ADJUST FIRE	Recover Sight Picture (NO)+ Observe/Announce Round Effect (YES) Announce REENGAGING (YES) Release/Reengage Palm Switches (YES) Observe/Announce Deflection and Range Error (YES)

	Adjust 1 mil Deflection (YES) Adjust 200 Meters Range (YES)
6. ENGAGE MULTIPLE TARGETS WITH THE MAIN GUN	If First Target not Destroyed, Adjust Fire (YES)
7. ENGAGE TARGETS USING DEGRADED GUNNERY TECHNIQUES	Set LRF:SAFE (YES) Set Gun Select:MAIN (NO) Sight Through GAS (NO) Grasp Palm Switches (YES) Announce IDENTIFIED (YES) Lay Announced Range Line on Target (NO)+ Lead Moving Target (YES) Listen for FIRE (NO)+ Announce ON THE WAY (YES) Squeeze Trigger (YES) Continue Tracking (YES)

* From Hoffman and Morrison (1987; Appendix G-2-1)
\+ Items which have since been changed/improved.

APPENDIX B

Breakdown of VIGS Gunnery Activities and Evaluation of Trainability*

BROAD CATEGORY	ACTIVITIES TRAINABLE
1. PREOPS CHECKS	Perform TIS Check (NO) Check Power Control Handles (YES)
2. PREFIRE CHECKS	Report Weapon Status (YES) Index Battlecarry Ammo on Ammo Select Switch (YES) Receive TC Briefing (YES)
3. ACQUIRE TARGETS	Estimate Range to Evaluate LRF Return (NO)
4. ENGAGE SINGLE TARGETS WITH MAIN GUN	LRF: Arm Last Return (NO)+ Gun Select: MAIN (NO)+ Ammo Select as Announced (YES) Sight Through GPS (YES) Grasp Palm Switches (NO)+ Look Through GPS (YES) Announce IDENTIFIED (YES) Lay on Target Center of Mass (YES) Track Moving Target (NO)+ Depress Lase Button (NO)+ Squeeze Trigger (YES) Continue Tracking (NO)+ Thermal Mode:ON (YES) Evaluate Range Display (YES) FLTR/CLEAR/SHUTTR: SHUTTR (YES) Check Ready to Fire and Faults (NO) Sensitivity, Contrast, and Focus for Best Image (YES) Make Control Lay (YES) Listen for UP (NO)+ Listen for FIRE (NO)+ Polarity Switch (NO)+ Announce ON THE WAY (YES)
5. ADJUST FIRE	Recover Sight Picture (NO)+ Observe/Announce Round Effects (NO)+ Announce REENGAGING (YES) Release/Reengage Palm Switches (NO)+ Announce Deflection and Range Error (Yes)

	Adjust 1 mil Deflection (NO) Adjust 200 meters range (NO)
6. ENGAGE SINGLE TARGETS WITH MAIN GUN	LRF:Arm LST RTN (NO)+ GPS:3x (NO) Gun Select:COAX (NO)+ Grasp Palm Switches (NO)+ Announce IDENTIFIED (YES) Lay on Center of Mass (YES) Depress Lase Button (NO)+ Evaluate Range Display (YES) Listen For FIRE (YES) Announce ON THE WAY (YES) Fire 20-30 Round Burst (YES) Adjust Fire (YES)
7. ENGAGE MULTIPLE TARGETS WITH MAIN GUN	Adjust Fire (NO)+
8. ENGAGE TARGETS USING DEGRADED GUNNERY TECHNIQUES	LRF:Safe (NO)+ Gun Select:MAIN (NO)+ Ammo Select (YES) Reengage Target Using Precision Gunnery Without Lasing To Target (NO)
9. ASSESS RESULTS OF ENGAGEMENT	Index Battlecarry Ammo (NO) Announce IDENTIFIED (YES)

* From Hoffman and Morrison (1987; Appendix G-1-1)
\+ Items which have since been changed or improved.

APPENDIX C

Task analysis of trainable behaviors on TOPGUN, VIGS, COFT.

Device Conditions:

Parameters	Conditions	VIGS	Device TOPGUN	UCOFT
Target Type	a. Tank	YES	YES	YES
	b. pers. carrier	YES	NO	YES
	c. helicopter	YES	NO	YES
	d. bunkers	NO	NO	NO
	e. antitank	NO	NO	NO
	f. truck	YES	NO	YES
	g. troops	YES	NO	YES
	h. aircraft	NO	NO	NO
Target Movement	a. sta. front	YES	YES	YES
	b. sta. flank	YES	YES	YES
	c. sta. oblique	YES	YES	YES
	d. mov. flank	YES	YES	YES
	e. mov. oblique	YES	YES	YES
	f. mov. zig-zag	YES	YES	YES
	g. mov. approach	YES	YES	YES
	h. mov. retreating	NO	YES	YES
Target Array	a. single targets	YES	YES	YES
	b. multiple targets	YES	YES	YES
	c. both sing. & mult.	NO	YES	NO
Target Range	a. < 900 meters	YES	NO	YES
	b. 900-1800 meters	YES	YES	YES
	c. > 1800 meters	YES	YES	YES
Ident. of targets	a. threat	YES	YES	YES
	b. friendly	NO	NO	YES
	c. mixed	NO	NO	YES
Supply shortages simulated?	a. none	YES	YES	YES
	b. ammo	YES	YES	NO
	c. fuel	NO	NO	NO
	d. food	NO	NO	NO
Mission type	a. offense (moving)	YES	NO	YES
	b. defense (stationary)	YES	YES	NO

Gunnery Behavior Represented Per Device:

Activity	Options	VIGS	Device TOPGUN	COFT
Prepare Operations	a. prepare offensive	NO	NO	YES
(PREOPS)	b. prepare defensive	NO	NO	NO
Prepare-to-fire	a. prepare offensive	YES	NO	YES
(PREFIRE)	b. prepare defensive	NO	NO	NO
Acquire Targets	a. search for targets	YES	YES	YES
	1. open hatch (day)	NO	NO	NO
	2. closed hatch	60%	100%	100%
	3. night search	60%	100%	100%
	b. detect/locate/I.D.	NO	YES	YES
	c. evaluate situation	N/A	N/A	30%
Engage single target with main gun	a. offensive engage	YES	NO	YES
	b. defensive engage	YES	YES	YES
	c. thermal sighting	YES	YES	YES
	d. magnif. choice	YES	YES	YES
Adjust fire	a. use reengagement procedures	NO	NO	YES
	b. use standard adjustment	YES	YES	YES
	c. use T.C. adjust	N/A	N/A	YES
Engage single target with COAX		YES	NO	YES
Engage mult. targets with main gun		YES	YES	YES
Engage targets with cal. 50		N/A	N/A	YES
Engage targets under degraded conditions	a. battlesight guns	YES	YES	YES
	b. ineffective LRF	YES	YES	YES
	c. multiple returns from LRF	NO	YES	YES
	d. no range display	NO	NO	50%
	e. crosswind sensor failure	NO	NO	50%
	f. cant sensor fail	NO	NO	50%
	g. lead angle sensor failure	NO	NO	NO
	h. GPS failure	YES	YES	YES
	i. GPS/TIS failure	NO	NO	YES
	j. stabilization system failure	NO	NO	YES
	k. loss of turret power	NO	NO	YES

Engage from T.C. position	N/A	N/A	YES
Assess Results of Engagement	NO	NO	50%

APPENDIX D

Overall Rankings of Task Transferability by Broad Category

TOPGUN to UCOFT		VIGS to UCOFT	
1	Engage Multiple Targets with main gun.	1	Engage Multiple Targets with main gun
2	Engage Targets using TIS	2	PREFIRE
3	Engage Single Target from Defense Using Precision Gunnery	3	Engage Targets using Battlesight Gunnery
4	PREOPS	4	Assess Engagement Results
5	PREFIRE	4	Engage Single Target w/ COAX
5	Adjust Fire	4	Adjust Fire
5	Engage Targets using GAS	5	Engage Targets using TIS
6	Acquire Targets	6	Acquire Targets
		7	PREOPS

*Data from Hoffman and Morrison (1987, p. 53-59)

Listing of Gunnery Behaviors that are Untrainable by Broad Category

TOPGUN	VIGS
Assess Immediate Results of Single Engagement	Engage Single Target From Offense Using Precision Gunnery
Engage Targets from TC Position	Engage Targets with the Cal. 50
Engage Targets in Manual Mode	Engage Targets Given Fire Control System Failure
Engage Targets in Emergency Mode	Engage Targets Using GAS
Engage Targets Given Fire Control System Failure	Engage Targets in Emergency Mode
Engage Targets Using Battlesight Gunnery	Engage Targets in Manual Mode
Engage Targets Using Cal. 50	Engage Targets from TC Position
Engage Single Targets with COAX	

APPENDIX E

Sign-up Sheet for Tank Gunnery Transfer Experiment

A T T E N T I O N !!

Students are needed to participate in an experiment which will investigate the transfer of tank gunnery skills trained on two part- task gunnery trainers to a whole-task gunnery trainer.

Students, in order to be included, must fulfill the following requirements:

1) Must be of the male gender.

2) Must be a UCF student.

3) Must be able to participate for a total of 16 hours, broken up as follows:

   a. First, four hours will be required the first week, in which testing will be administered.

   b. Second, students will be required to participate for 2 hours per day for 4 consecutive days during the second week.

   c. Third, students must be able to travel to Daytona for one day during the third week, for 3 hours of off-site training. (Travel time not included)

4) The ideal subject will be of Freshman or Sophomore standing.

Students may be placed in one of two experimental conditions: either a full experimental condition, in which "a", "b", and "c" of number 3 are fulfilled; or a control condition, in which only "a" and "c" are fulfilled.

At the termination of the experiment, students will be paid at the rate of approximately $5.00 per hour for their participation. Therefore, students who are in the experimental condition, putting in approximately 20 hours of work, will be paid $100.00 for their services; and students in the control condition, who fulfill only steps "a" and "c" of number 3, above, will be paid $50.00 for their participation via OPS contract.

STUDENT (Name and S.S. #)	TIMES AVAILABLE	PHONE #

APPENDIX F

Subject Background Information

The purpose of this questionnaire is to collect background information on soldiers participating in the IST/ARI transfer of training research. This information will be used strictly for research purposes only. Please complete each item to the best of your ability. Write "N/A" for each item you cannot answer.

1. Name:____
   Last   First   M.I.

2. Social Security Number:_______-______-________

3. Date of Birth:_____/____/_____

4. Present grade classification (Junior, Senior, etc.)______________

5. Length of time spent in ROTC____________________

6. Of what branch ROTC are you a member (Air Force or Army)________________

7. How often do you play video games (circle one)?

   A. less than once per week
   B. once per week
   C. 2-4 times a week
   D. greater than 4 times/week

APPENDIX G

Informed Consent Form for The Use of Surrogate Measures in Tank Gunnery Transfer

In this experiment, we are going to measure the degree of transfer that occurs between two part-task gunnery simulators and a full-fidelity tank gunnery trainer. In order to do this we will be administering four predictor tests to determine factors which might influence simulator performance. Your participation will be needed for approximately 16 hours, allocated as follows: 1) Four hours the first week, at a preassigned time; 2) Eight hours the second week (2 hours/day for 4 consecutive days). Control subjects will not receive this training; 3) Four hours the third week, at a preassigned time.

The experiment will be carried out in the Human Factors Laboratory of the Institute for Simulation and Training by Dr. Janet Turnage, Department of Psychology (275-2910) and her associates.

On some of the tests and simulator tasks you will notice that your performance will improve. This is due to learning and it is one of the issues we are studying in this experiment. As with all test batteries (a test composed of several individual tests that measure different abilities), and simulated tasks, there will be items and tasks which are easy and those which are difficult. No one is expected to be able to perform perfectly, but we ask that you perform as accurately and as quickly as possible. Therefore, please do not serve as a subject any time that you are not in your usual state of fitness, mentally and physically. During the period of the experiment if you go on medication, experience heavy pressure or stress, end up not getting a good night's sleep, or take more than one or two cups of coffee or alcoholic beverages in the last 24 hours, we ask that you alert the experimenter, or reschedule your session.

All data will be encoded numerically to ensure every subject's confidentiality and anonymity. The coded data will be examined only by the members of the research team, and you are assured that the data will not be used for any purpose other than the scientific goals of this experiment. Your data will be stored on both diskette and paper, so that no one except the experimenters will have access to your scores. Participation in this study is voluntary, and refusal to participate will not result in any penalty or loss of benefits to which one is otherwise entitled. Anyone who wishes to withdraw from participation may do so at any time. As a participant in this study you will receive $5.00 per hour. Therefore, control subjects will be paid $50.00, experimental subjects will be paid $100.00, and subjects who withdraw will be paid on a pro-rata basis. Thank you for your participation in this experiment.

I, ____________________ have read this Informed Consent Form on
Your Name

____________________, and fully understand the information above.
Today's Date

S.S. ____________________

APPENDIX H

Target Sequences for Each Simulator; Tank Gunnery Transfer Study

TOPGUN

Targets 1, 2, 3:	Stationary, Single, Primary Sights
Targets 4, 5:	Stationary, Single, Thermal Sights
Targets 6, 7:	Moving, Single, Primary Sights
Targets 8, 9, 10:	Moving, Single, Thermal Sights
Targets 11, 12, 13, 14, 15, 16:	Multiple (stationary and moving mix), Primary Sights
Targets 17, 18, 19, 20:	Multiple (stationary and moving mix), Thermal Sights
Targets 21, 22, 23, 24:	Stationary, Single, Secondary Sights
Targets 25, 26, 27, 28:	Moving, Single, Secondary Sights
Targets 29, 30, 31, 32, 33, 34, 35, 36:	Multiple (stationary and moving mix), Secondary Sights

VIGS

Targets 1, 2, 3, 5, 6:	Stationary, Single, Primary Sights
Target 4:	Stationary, Single, Thermal Sights
Target 8:	Moving, Single, Primary Sights
Targets 7, 9:	Moving, Single, Thermal Sights
Targets 10, 11, 14, 15, 22, 23, 26, 27, 30, 31:	Multiple (moving and stationary mix), Primary Sights
Targets 12, 13, 16, 17, 18, 19, 20, 21, 24, 25, 28, 29:	Multiple (moving and stationary mix), Thermal Sights
Target 32:	Stationary, Single, Secondary Sights
Targets 33, 34, 35:	Moving, Single, Secondary Sights
Targets 36, 37, 38, 39, 40, 41:	Multiple (moving and stationary mix), Secondary Sights

ICOFT

31211	Targets:	Stationary, Single, Primary Sights
31411	Targets:	Moving, Single, Primary Sights
32412	Targets:	Moving, Single, Thermal Sights
33211	Targets:	Stationary, Multiple, Primary Sights
33411	Targets:	Moving, Multiple, Primary Sights
32261	Targets:	Stationary, Single, Secondary Sights

APPENDIX I

Instructions for Subjects
(Skills Transfer of Training in Tank Gunnery
Simulation Systems)

Approx.
Time

1. On the first day that you report to IST for the experiment you will be asked to fill out certain forms for administrative purposes and take a colorblind screening test.

Approx. Time	
1 min.	a. Informed Consent- please read and sign, fill in SS#.
1 min.	b. OPS Contract- read and sign; you will sign again at completion of experiment and will receive payment approximately 3-4 weeks afterward.
1 min.	c. Background Information- please fill out completely, then write on back of sheet: Name, SS#, address, (to be later filled out on OPS contract).
1 min.	d. Colorblind Test- view the plate through stereoscope, adjusting the plate forward and backward until in focus; the numbers which you see in the circles labelled A, B, C, and D:

A__________ B__________ C__________ D__________

2. Next you will be given a series of tests to measure various sensory, perceptual, cognitive, psychomotor, and motivational facets of individuals. The order of testing and a brief description of the tests follows:

3 mins.	a. VISTECH- Stand 10 ft. from the contrast sensitivity plates and , with both eyes open, tell the experimenter whether the lines within each of the circles go to the left, right, straight up, or are nonexistent.
15-25 mins.	b. Automated Performance Test System- Turn the minicomputer on at right side of machine and wait until the computer asks whether you are a "qualified user" - if this is your first trial, type "N" and enter your SS#. All following trials, type "Y", enter SS#, and proceed - the first trial is a practice session in which you will be given instructions for each test and be allowed to practice for a short period. If you miss more than 40% of the items or get more than 5 incorrect in a row, the computer will stop and tell you to see the experimenter. If the experimenter is not

available, press <Ctrl-R> and you will start that particular test over again. Be sure to read the instructions carefully and be especially careful that you are pressing the correct keys for your responses. You will receive feedback on the first trial, but none on the three test trials to follow.

1 hr.+	c.	ASVAB- This paper and pencil test will take a total of 1 hour to take. Turn the tape recorder and follow the instructions. If you need help at any time, find the experimenter (usually in TOPGUN and VIGS area) for assistance.
15 mins.	d.	BREAK- You may go to the cafeteria down the hall (to left); rest rooms are also there.
15 mins.	e.	APTS- This will be your second APTS trial; enter your SS# and proceed, following computer-generated instructions.
10-15 mins.	f.	Work and Family Orientation Questionnaire- Follow the written instructions and respond to items 1-23.
15 mins.	g.	APTS- This is your third and last administration; follow instructions as before.
3 mins.	h.	VISTECH- This is the second administration of the contrast sensitivity plates; follow instructions as before.

3. Check with experimenter to verify the time and place for your next experimental session before leaving.

THANK YOU FOR YOUR PARTICIPATION!!

APPENDIX J

TOPGUN Instructions

Hi! My name is ____________________ with the Institute for Simulation and Training here at UCF. Today you will train for approximately 2 hours on the TOPGUN tank gunnery trainer.

Please seat yourself inside the trainer. TOPGUN is an arcade-type trainer which has few knobs to manipulate. With TOPGUN, soldiers can train or sharpen their gunnery skills in a competitive environment.

In front of you, you will see two connected handles (cadillacs). These cadillacs move the gun tube up, down, and side to side. To move the reticle (crosshairs) side to side, turn the handle like a steering wheel. To move the reticle up or down, twist the handles accordingly. (demonstrate).

You will also notice two sets of buttons. The first set of buttons, located near the top and inner portions of the handles, controls the laser rangefinder mechanism. This gives you a "lock" on the target, as well as computing the target's range which is shown on the screen. The second set of buttons, located near the index fingers' position, are the fire buttons. Finally, in order for any buttons or movements to work, THE PALM LEVERS ON THE FRONT OF THE CADILLAC HANDLES MUST BE ENGAGED!!!

Therefore, when engaging a target, the sequence of activities is as follows:

1. Squeeze palm levers and hold them down.
* 2. Manipulate cadillacs to bring reticle to desired position (on target).

When manipulating the cadillacs, be sure that the last movement of the reticle onto the target is in an upward motion. Also, when reengaging the target, be sure to "dump lead" by disengaging and reengaging the palm levers! (demonstrate)

3. Activate Laser Rangefinder.
4. While still tracking the target, press the fire button.
5. Assess results and reengage target if necessary.
6. Disengage palm levers.

When playing TOPGUN, an automated tank commander will move you close to the target to be engaged. He will then give you the order to fire. When shooting more than once, you must wait for the "UP" signal before firing. This indicates that a shell is chambered and ready to fire. Firing before the "UP" or "FIRE" commands will result in penalties being assessed against your score.

There are three modes of operation that you will use in the following engagements. These are GPS (Gunner's Primary Sight), GAS (Gunner's Auxiliary Sight), or TIS (Thermal Imaging System). At the start of each engagement, I will tell you which mode you will operate in and it will be your responsibility to switch manually to that particular mode. A toggle switch to your left enables you to operate in GPS or GAS mode. The "Sight Select" switch must be set to "PRIMARY" for GPS mode and "SECONDARY" for GAS mode. For TIS, the "Sight Select" switch must be set to "PRIMARY" and the toggle switch to your right (thermal mode) must be set to "ON".

When the automated tank commander announces a target and slews you toward it, it will be your responsibility to switch from Magnification "3x" to Magnification "10x". After confronting the target, the commander will say "cease fire". At this point, you should switch back to "3x", in preparation for the next target.

Are there any questions regarding these instructions?

APPENDIX K

VIGS Instructions

Hi! My name is ____________________ with the Institute for Simulation and Training here at UCF. Today you will train for approximately 2 hours on the VIGS tank gunnery trainer.

Please have a seat in front of the trainer. VIGS is a trainer which utilizes videodisk technology to present 30-45 second engagements to the trainee. There are more switches and knobs that need to be manipulated than on TOPGUN. In front of you, you will see two connected handles (cadillacs). These cadillacs move the gun tube up, down, and side to side. To move the reticle (crosshairs) side to side, turn the handle like a steering wheel. To move the reticle up or down, twist the handles accordingly. (demonstrate)

You will also notice two sets of buttons. The first set of buttons, located near the top and inner portions of the handles, controls the laser rangefinder mechanism. This gives you a "lock" on the target, as well as computing the target's range which is shown on the screen. The second set of buttons, located near the index fingers' position, are the fire buttons. Finally, in order for any buttons or movements to work, THE PALM LEVERS ON THE FRONT OF THE CADILLAC HANDLES MUST BE ENGAGED!!!

Therefore, when engaging a target, the sequence of activities is as follows:

1. Squeeze palm levers and hold them down.
*2. Manipulate cadillacs to bring reticle to desired position (on target).

When manipulating the cadillacs, be sure that the last movement of the reticle onto the target is in an upward motion! Also, when reengaging the target, be sure to "dump lead" by disengaging and reengaging the palm levers! (demonstrate)

3. Activate Laser Rangefinder.
4. While still tracking the target, press the fire button.
5. Assess results and reengage target if necessary.
6. Disengage palm levers.

Now, look at the panel in front of you. you will notice a screen embedded within the panel. When an engagement begins, you must look at the screen to determine the type of mission which is forthcoming. There are two possibilities:

1. "Initiating Mission". In this case, the shutter switch needs to be set on "clear" and the thermal mode switch must be on "standby".

2. "Initiating Thermal Mission". In this case, the shutter switch must be turned clockwise to "SHUTTR". Also, the thermal mode switch must be set to "ON".

After proper setting of the shutter and thermal mode switches, the engagement will begin. An automated tank commander will slew you to the target, while instructing you as to the type of ammunition required to be used (i.e., "GUNNER, SABOT" or "GUNNER, HEAT").

After hearing this, you must manipulate the switch above the screen (reticle selection switch) and the ammo selection switch accordingly.

At this point, you should place the reticle on the target, press the laser rangefinder button, and fire, continuously tracking.

Are there any questions regarding these instructions?

APPENDIX L

GAS Sighting Instructions

The following few engagements will use the manual reticle you see on the screen. When the automated tank commander slews you to the target, he will announce a range (i.e., "one four hundred, one two hundred, etc.). Upon hearing that range, place the reticle line corresponding to it on the target ("14" corresponds to "one four hundred, etc.). Also, apply lead if the target is moving!

Do you have any questions regarding these instructions?

```
          ------------
     --------     ---------8
     .    ------0------     .  12
     --------     ---------16
     .    -------------     .  20
     ---------    ---------24
             .      .          28
```

APPENDIX M

Subject Opinion Questionnaire

Subject No.________

The purpose of this questionnaire is to collect subjects' opinions about the devices they used in the IST/ARI transfer of training research. This information will be used strictly for research purposes only. Please complete each question to the best of your ability. Write "N/A" for each item you cannot answer.

Part One -- TOPGUN

The following survey questions pertain only to the TOPGUN trainer. Please indicate how much you agree or disagree with the following statements. Read each statement carefully, then choose the number from the scale below that matches your feelings about the statement. If you have other opinions regarding TOPGUN that are not covered in the survey please elaborate upon these in the comments section.

1	2	3	4	5
Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree

1. _____ I enjoyed training on the TOPGUN device.
2. _____ TOPGUN helped me to improve/learn tank gunnery skills.
3. _____ If I could see the target, I could hit it.
4. _____ Most of the target engagements were too difficult.
5. _____ If given a choice, I would use TOPGUN to train on.
6. _____ I could use TOPGUN without any instructor assistance.
7. _____ I thought TOPGUN engagements were too easy.
8. _____ I had trouble finding targets on TOPGUN.
9. _____ I liked the "unity window" for locating targets.
10. _____ The skills trained on TOPGUN were the same as on ICOFT.
11. _____ The device features on TOPGUN (color coding of targets, etc) were helpful when learning to hit the targets.
12. _____ Prior TOPGUN training helped my performance on ICOFT.

COMMENTS:____

Subject No.______

Part Two -- VIGS

The following survey questions pertain only to the VIGS trainer. Please indicate how much you agree or disagree with the following statements. Read each statement carefully, then choose the number from the scale below that matches your feelings about the statement. If you have other opinions concerning VIGS, please write them in the comments section.

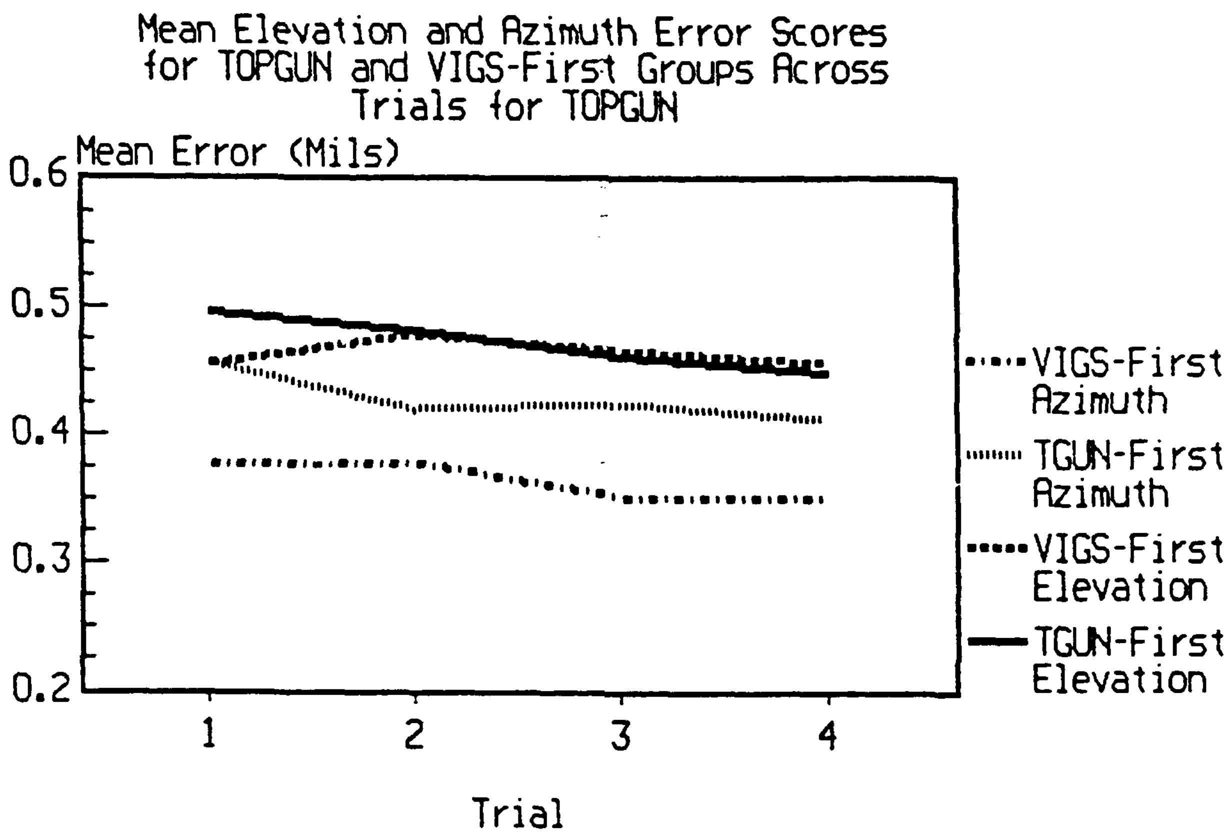
1	2	3	4	5
Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree

1.____ I enjoyed training on the VIGS device.
2.____ VIGS helped me to learn/improve my gunnery skills.
3.____ If I could see the target, I could hit it.
4.____ Most of the engagements were too difficult.
5.____ If given a choice, I would choose the VIGS to train on.
6.____ I could use VIGS without any instructor assistance.
7.____ I thought the VIGS engagements were too easy.
8.____ I had trouble finding targets on VIGS.
9.____ I was confused by the adjustments required by VIGS.
10.___ The skills trained on VIGS were the same as on ICOFT.
11.___ The voice on VIGS was difficult to understand.
12.___ Prior VIGS training helped my performance on ICOFT.

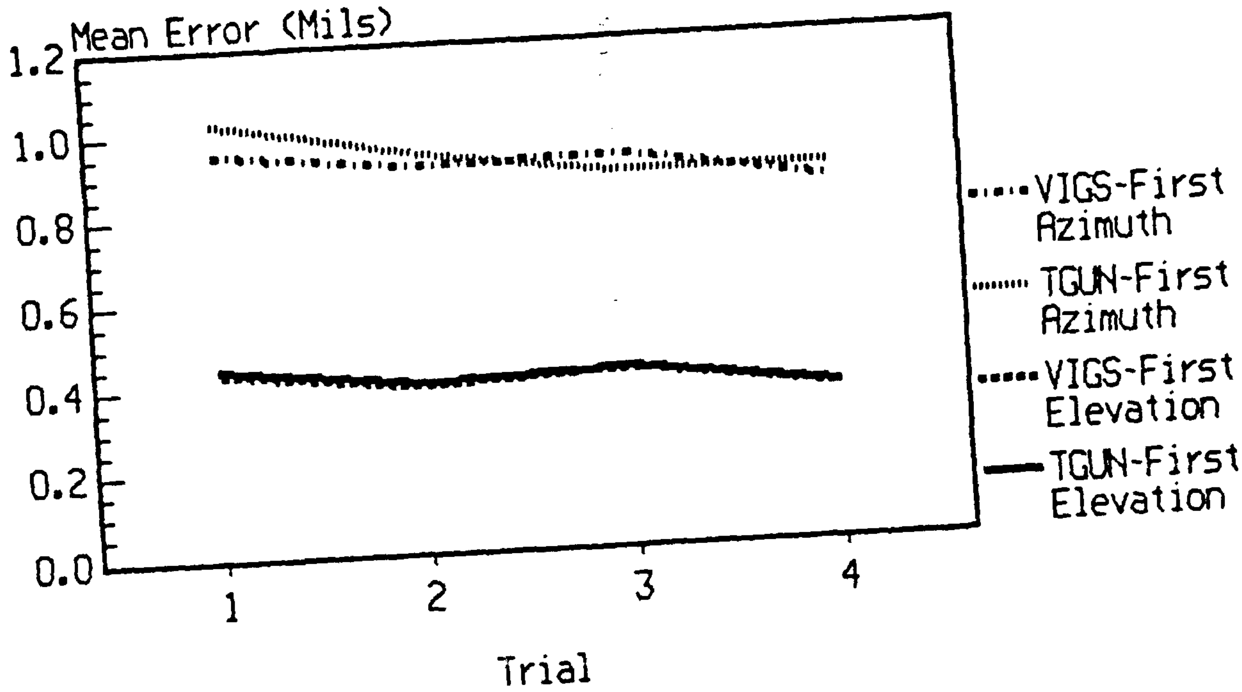
COMMENTS:____
____
____
____
____

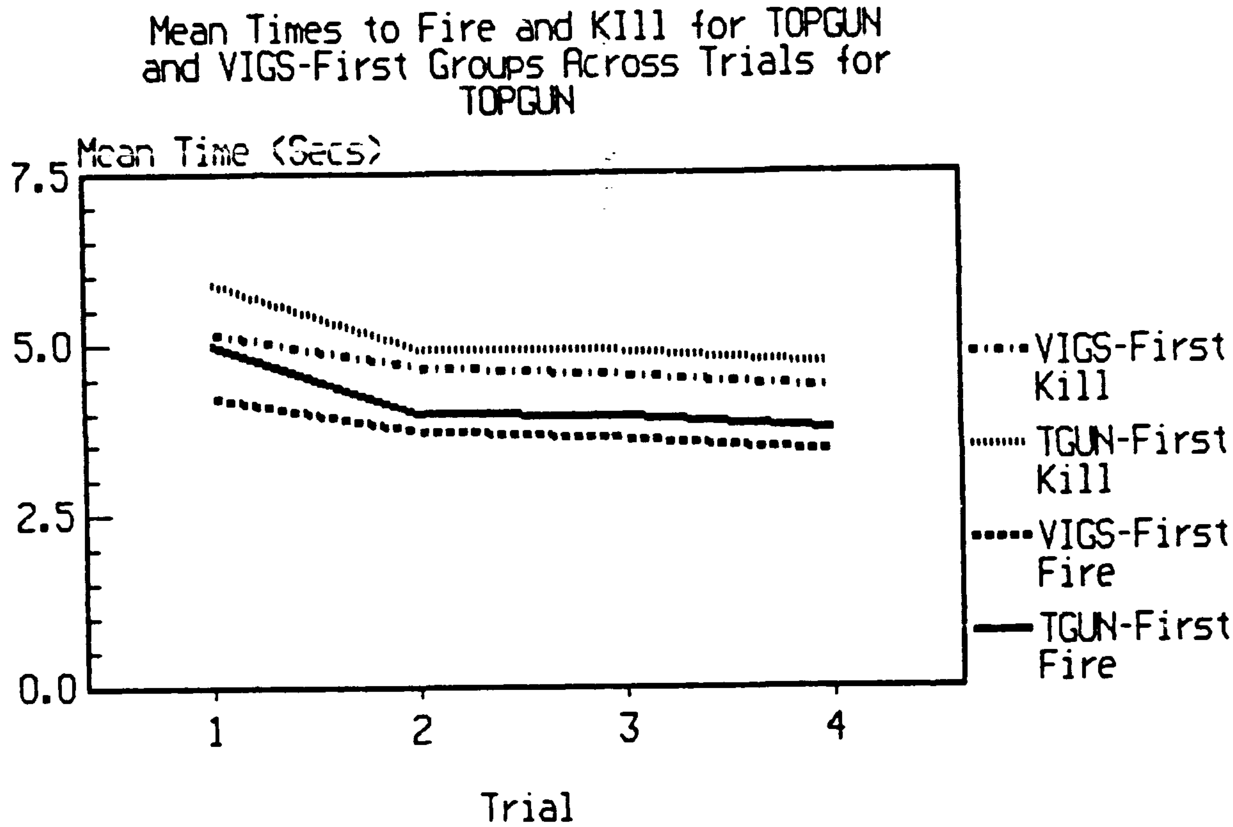
APPENDIX N

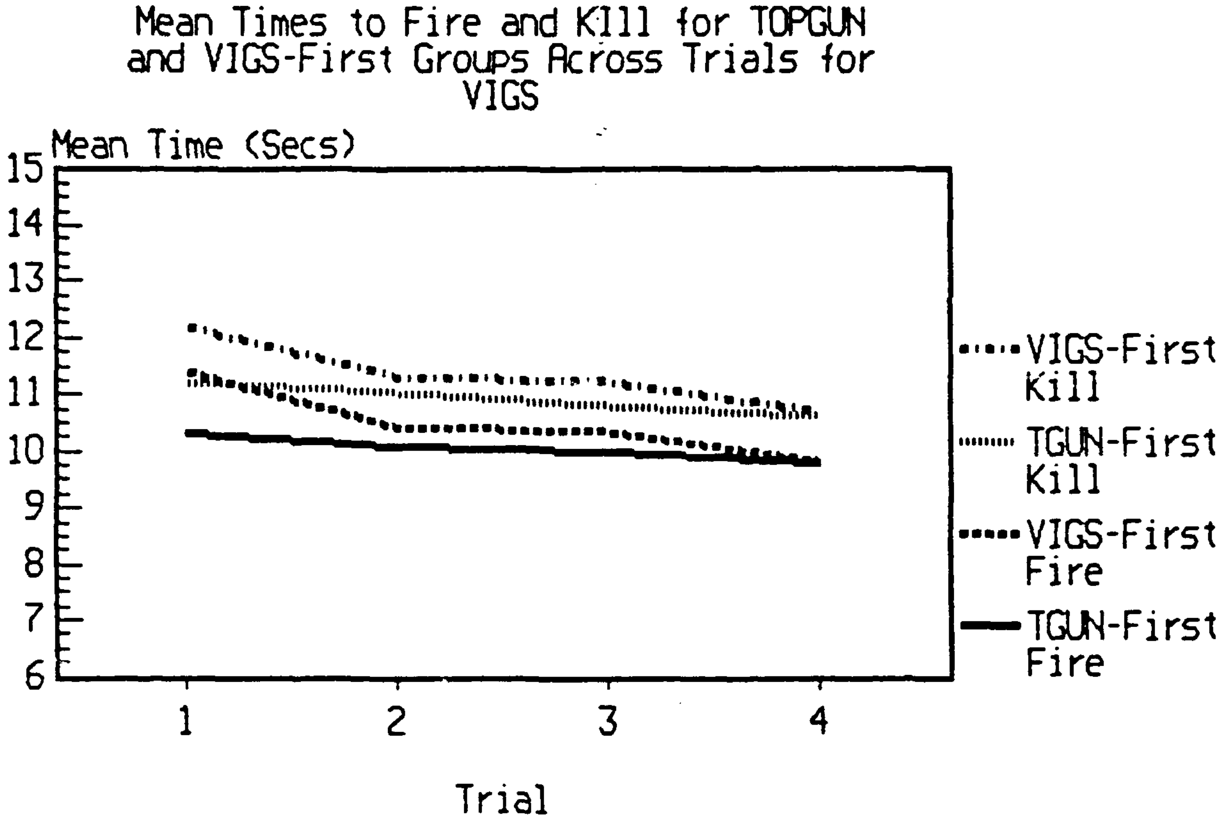
Mean Performance Measures Across Trials for TOPGUN and VIGS

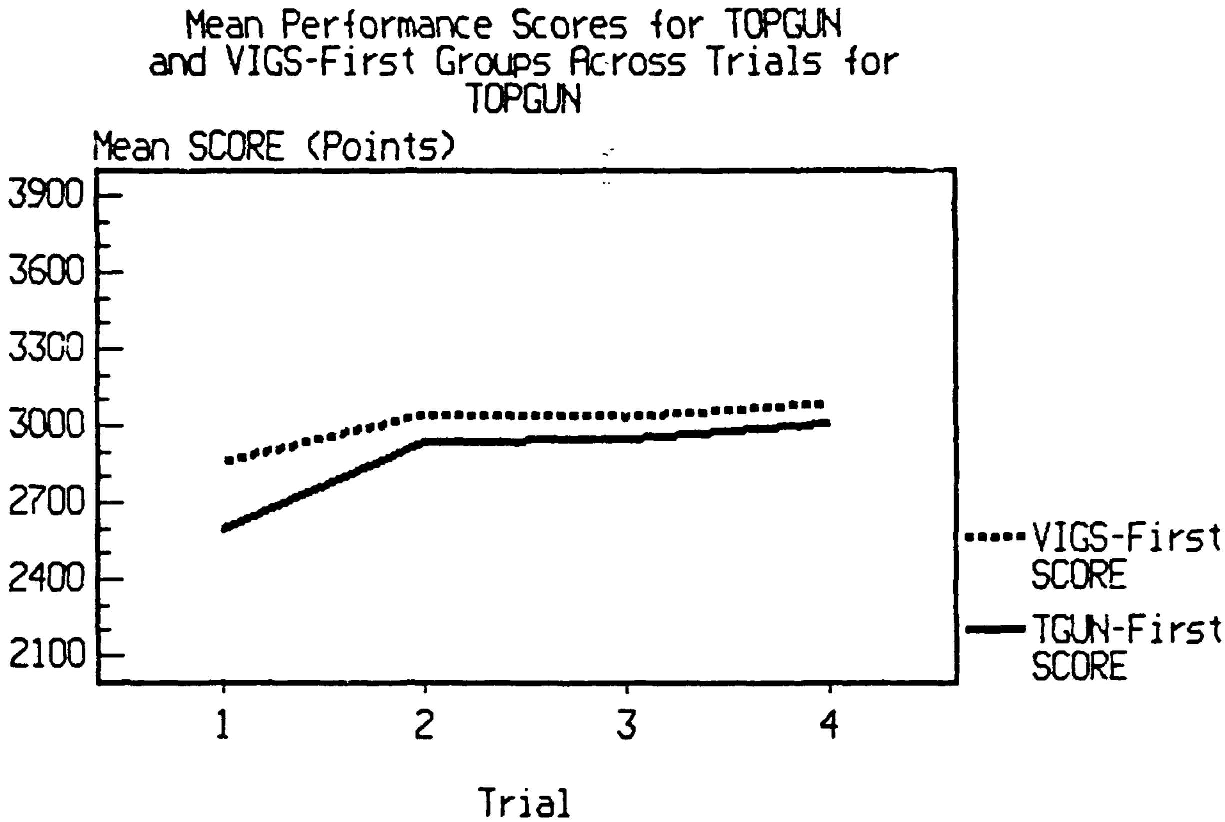


Mean Elevation and Azimuth Error Scores for TOPGUN and VIGS-First Groups Across Trials for VIGS.

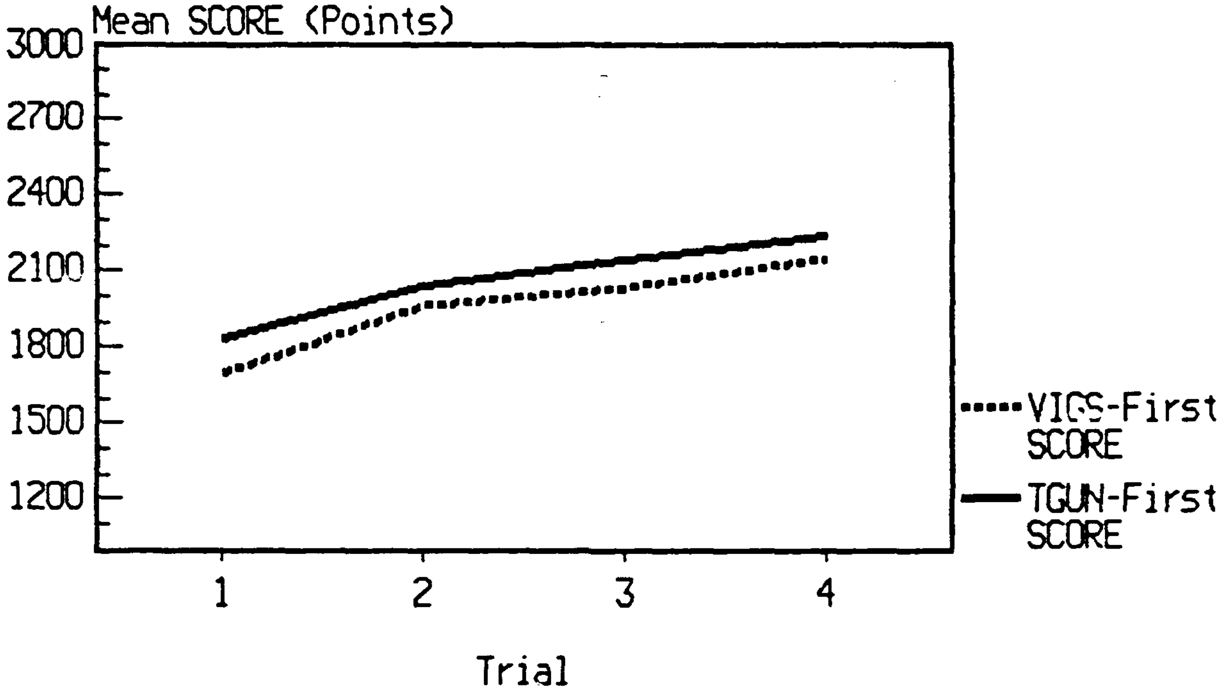



Mean Times to Fire and KIll for TOPGUN and VIGS-First Groups Across Trials for TOPGUN
Mean Time (Secs)
7.5
5.0
2.5
0.0
1
2
3
4
Trial
VIGS-First Kill
TGUN-First Kill
VIGS-First Fire
TGUN-First Fire

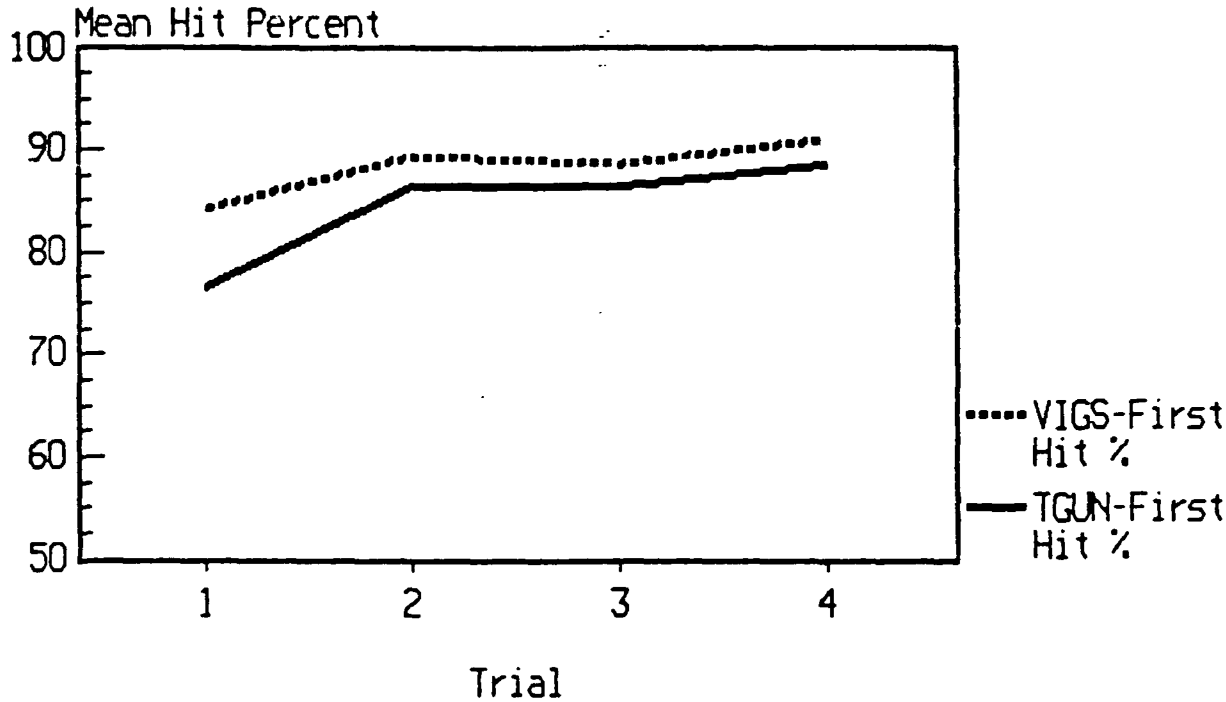

Mean Times to Fire and Kill for TOPGUN and VIGS-First Groups Across Trials for VIGS
Mean Time (Secs)
15
14
13
12
11
10
9
8
7
6
1
2
3
4
Trial
VIGS-First Kill
TGUN-First Kill
VIGS-First Fire
TGUN-First Fire


Mean Performance Scores for TOPGUN
and VIGS-First Groups Across Trials for
TOPGUN
Mean SCORE (Points)
3900
3600
3300
3000
2700
2400
2100
1
2
3
4
Trial
VIGS-First
SCORE
TGUN-First
SCORE

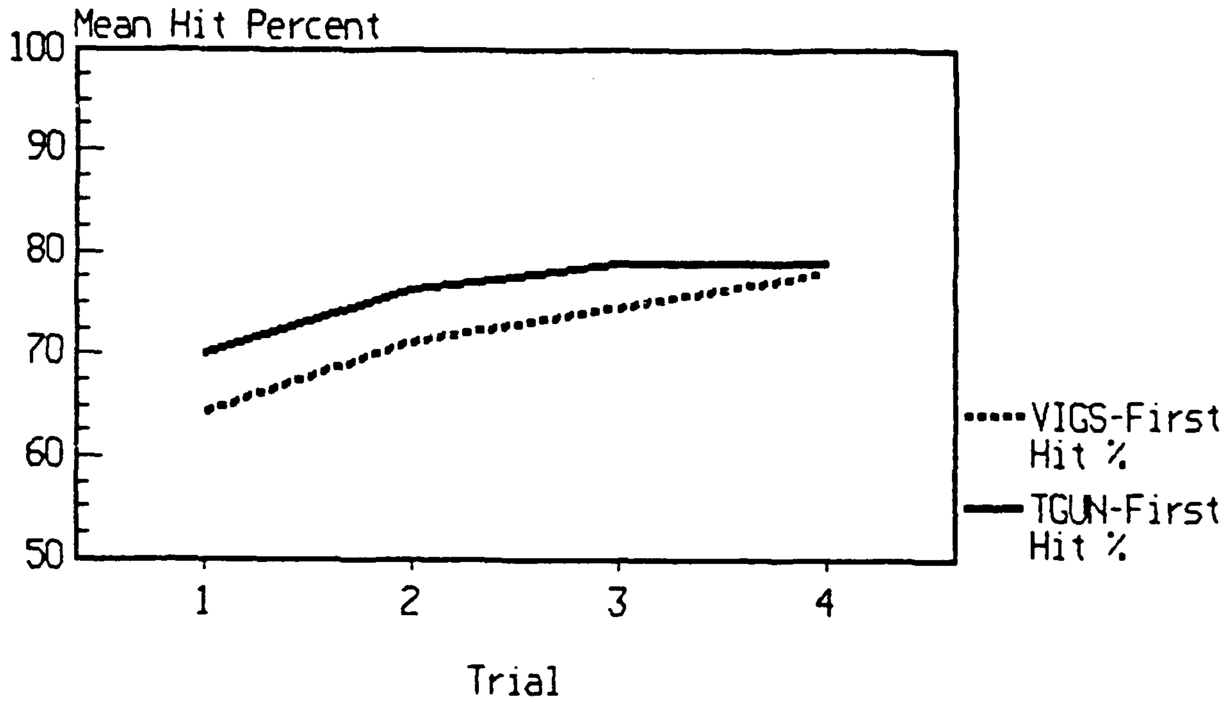
Mean Performance Scores for TOPGUN and VIGS-First Groups Across Trials for VIGS



Mean Hit Percentages for TOPGUN
and VIGS-First Groups Across Trials for
TOPGUN



Mean Hit Percentages for TOPGUN
and VIGS-First Groups Across Trials for
VIGS



Appendix O

Raw Data for ICOFT by Dependent Variable, Group, and Exercise

SUBNUM	GROUP	ICEXNUM	ICFIRE	ICKILL	ICERROR	ICVGRADE	ICHITPC
1	0.0	31211	17.7	17.3	0	2.00	100.00
1	0.0	31311	13.4	14.9	6	2.00	44.44
1	0.0	32261	14.5	16.7	0	2.00	87.50
1	0.0	32321	17.7	21.2	4	2.00	50.00
1	0.0	33211	19.3	18.1	4	2.00	88.89
1	0.0	33311	15.4	19.5	12	1.00	66.67
2	0.0	31211	14.9	15.4	0	3.00	100.00
2	0.0	31311	17.6	21.3	4	1.00	36.36
2	0.0	32261	13.4	17.6	4	2.00	83.33
2	0.0	32321	19.1	17.8	4	2.00	40.00
2	0.0	33211	18.5	20.5	0	2.00	83.33
2	0.0	33311	19.0	21.2	7	1.00	60.00
3	0.0	31211	18.4	18.8	6	2.00	66.67
3	0.0	31311	15.8	19.3	0	2.00	33.33
3	0.0	32261	18.8	16.4	0	2.00	77.78
3	0.0	32321	16.6	19.2	8	1.00	28.57
3	0.0	33211	18.0	18.7	3	2.00	72.73
3	0.0	33311	15.6	18.3	10	1.00	60.00
4	0.0	31211	14.7	15.1	4	2.00	71.43
4	0.0	31311	14.2	17.5	4	2.00	26.67
4	0.0	32261	17.6	20.1	0	2.00	17.50
4	0.0	32321	15.3	0.0	4	1.00	0.0
4	0.0	33211	20.6	22.7	3	2.00	81.82
4	0.0	33311	22.1	21.0	3	1.00	70.00
5	0.0	31211	14.3	17.1	0	3.00	70.00
5	0.0	31311	19.7	17.2	6	1.00	22.22
5	0.0	32261	14.2	16.1	4	2.00	62.50
5	0.0	32321	14.0	16.6	4	1.00	0.0
5	0.0	33211	17.4	19.8	3	2.00	81.82
5	0.0	33311	14.4	13.2	11	1.00	11.11
6	0.0	31211	16.1	18.0	0	3.00	88.89
6	0.0	31311	14.4	14.6	0	2.00	63.64
6	0.0	32261	11.1	13.5	0	3.00	62.50
6	0.0	32321	17.5	18.1	0	1.00	16.67
6	0.0	33211	21.7	20.6	0	2.00	72.73
6	0.0	33311	18.9	19.1	6	1.00	66.67
7	0.0	31211	13.8	13.8	6	2.00	85.71
7	0.0	31311	14.7	16.5	0	2.00	42.86
7	0.0	32261	18.0	19.8	2	2.00	41.67
7	0.0	32321	17.1	25.4	8	1.00	0.0
7	0.0	33211	17.7	18.5	3	2.00	63.64
7	0.0	33311	17.6	16.9	6	1.00	75.00
8	0.0	31211	14.0	15.2	2	3.00	70.00
8	0.0	31311	13.8	18.6	6	2.00	33.33
8	0.0	32261	17.0	16.7	4	2.00	85.71
8	0.0	32321	14.9	0.0	6	1.00	0.0
8	0.0	33211	20.1	17.0	2	2.00	58.33
8	0.0	33311	12.3	14.0	11	1.00	33.33
9	0.0	31211	14.7	18.6	0	2.00	61.54
9	0.0	31311	18.7	19.6	0	2.00	81.82
9	0.0	32261	13.4	17.0	0	3.00	77.78
9	0.0	32321	15.3	18.0	2	2.00	63.64
9	0.0	33211	21.5	22.3	0	2.00	100.00
9	0.0	33311	22.7	22.3	3	2.00	88.89
10	0.0	31211	17.1	19.2	6	2.00	62.50
10	0.0	31311	5.0	20.7	4	2.00	38.46
10	0.0	32261	16.9	20.6	6	1.00	21.43
10	0.0	32321	17.7	0.0	14	1.00	0.0
10	0.0	33211	21.3	23.4	3	2.00	81.82
10	0.0	33311	20.5	25.1	10	1.00	12.50
11	0.0	31211	16.5	18.5	4	2.00	100.00

11	0.0	31311	17.8	17.3	6	2.00	33.33
11	0.0	32261	19.7	21.4	4	2.00	100.00
11	0.0	32321	20.1	25.3	14	1.00	0.0
11	0.0	33211	24.5	20.8	4	1.00	62.50
11	0.0	33311	18.4	22.5	10	1.00	57.14
12	0.0	31211	26.3	0.0	18	1.00	0.0
12	0.0	31311	21.9	25.6	16	1.00	50.00
12	0.0	32261	15.1	16.9	0	2.00	50.00
12	0.0	32321	18.5	13.6	6	1.00	8.33
12	0.0	33211	18.1	13.4	14	1.00	75.00
12	0.0	33311	19.4	14.9	8	1.00	30.00
13	0.0	31211	13.9	15.3	0	3.00	90.00
13	0.0	31311	12.7	14.7	2	2.00	33.33
13	0.0	32261	15.3	20.5	6	2.00	41.67
13	0.0	32321	13.3	15.4	0	2.00	12.50
13	0.0	33211	14.6	13.1	0	2.00	66.67
13	0.0	33311	16.9	17.1	10	1.00	37.50
14	0.0	31211	13.6	13.9	6	2.00	100.00
14	0.0	31311	14.2	16.9	0	3.00	75.00
14	0.0	32261	13.4	15.7	0	3.00	66.67
14	0.0	32321	14.6	0.0	2	1.00	0.0
14	0.0	33211	22.2	21.6	0	2.00	90.00
14	0.0	33311	16.8	19.7	7	1.00	66.67
15	0.0	31211	13.3	16.4	4	3.00	40.00
15	0.0	31311	11.1	17.3	2	2.00	33.33
15	0.0	32261	15.0	16.4	0	3.00	77.78
15	0.0	32321	12.0	0.0	2	1.00	0.0
15	0.0	33211	18.6	18.9	0	2.00	81.82
15	0.0	33311	15.2	13.7	13	1.00	20.00
16	0.0	31211	17.3	17.4	0	2.00	70.00
16	0.0	31311	14.0	16.3	2	2.00	50.00
16	0.0	32261	13.5	15.0	0	3.00	62.50
16	0.0	32321	18.7	20.0	6	1.00	28.57
16	0.0	33211	17.5	18.7	1	2.00	75.00
16	0.0	33311	19.1	20.1	5	2.00	87.50
17	0.0	31211	15.5	21.7	10	1.00	40.00
17	0.0	31311	18.6	21.1	4	1.00	27.27
17	0.0	32261	17.1	22.0	0	2.00	60.00
17	0.0	32321	19.3	23.2	6	1.00	33.33
17	0.0	33211	21.1	22.5	3	2.00	90.00
17	0.0	33311	20.0	15.8	8	1.00	33.33
18	0.0	31211	16.3	16.0	2	2.00	100.00
18	0.0	31311	17.4	18.3	2	1.00	45.45
18	0.0	32261	-99.0	-99.0	-99	-99.00	-99.00
18	0.0	32321	19.4	15.1	4	1.00	0.0
18	0.0	33211	16.3	18.3	2	2.00	45.45
18	0.0	33311	19.2	18.1	5	1.00	50.00
19	0.0	31211	17.7	18.6	0	2.00	88.89
19	0.0	31311	17.4	19.7	2	2.00	63.64
19	0.0	32261	12.3	14.7	0	2.00	87.50
19	0.0	32321	12.2	0.0	8	1.00	0.0
19	0.0	33211	18.1	20.[illegible]	8	1.00	85.71
19	0.0	33311	16.8	21.3	11	1.00	71.43
20	0.0	31211	15.6	15.0	4	2.00	100.00
20	0.0	31311	17.8	18.2	2	2.00	54.55
20	0.0	32261	12.3	14.2	0	2.00	54.55
20	0.0	32321	15.4	21.0	8	1.00	0.0
20	0.0	33211	17.5	19.9	4	2.00	80.00
20	0.0	33311	15.5	17.0	7	1.00	33.33
21	1.00	31211	17.4	19.3	0	2.00	100.00
21	1.00	31311	17.9	19.6	0	2.00	63.64
21	1.00	32261	12.6	15.0	0	3.00	88.89
21	1.00	32321	18.5	18.5	4	2.00	40.00

21	1.00	33211	22.8	22.7	0	2.00	90.00
21	1.00	33311	16.5	16.3	11	1.00	42.86
22	2.00	31211	15.3	18.4	0	2.00	77.78
22	2.00	31311	16.2	17.9	4	2.00	88.89
22	2.00	32261	16.8	19.0	2	2.00	85.71
22	2.00	32321	17.9	24.6	2	1.00	30.77
22	2.00	33211	22.5	23.3	3	2.00	100.00
22	2.00	33311	21.3	20.8	4	1.00	87.50
23	1.00	31211	14.8	16.1	0	3.00	100.00
23	1.00	31311	15.5	20.8	0	2.00	60.00
23	1.00	32261	13.8	15.6	0	3.00	100.00
23	1.00	32321	15.6	17.7	0	2.00	50.00
23	1.00	33211	21.4	22.2	0	2.00	100.00
23	1.00	33311	17.4	16.7	7	1.00	62.50
24	2.00	31211	14.5	15.8	4	2.00	77.78
24	2.00	31311	14.6	16.0	2	2.00	50.00
24	2.00	32261	12.5	15.3	2	2.00	66.67
24	2.00	32321	18.1	21.1	6	2.00	37.50
24	2.00	33211	17.4	19.4	8	1.00	85.71
24	2.00	33311	18.5	18.0	6	2.00	77.78
25	1.00	31211	12.3	13.2	0	3.00	100.00
25	1.00	31311	13.4	13.7	0	2.00	53.85
25	1.00	32261	14.0	16.0	0	3.00	55.56
25	1.00	32321	10.9	0.0	4	1.00	0.0
25	1.00	33211	18.9	19.3	0	2.00	81.82
25	1.00	33311	15.4	16.6	8	1.00	40.00
26	2.00	31211	11.9	13.4	0	3.00	100.00
26	2.00	31311	13.1	13.7	0	3.00	66.67
26	2.00	32261	12.6	15.5	0	3.00	87.50
26	2.00	32321	17.5	20.8	0	1.00	44.44
26	2.00	33211	18.6	19.4	2	3.00	100.00
26	2.00	33311	19.5	16.5	3	1.00	60.00
27	2.00	31211	15.0	15.7	0	3.00	88.89
27	2.00	31311	11.9	12.6	0	3.00	72.73
27	2.00	32261	11.9	14.0	0	3.00	10[illegible].00
27	2.00	32321	14.9	21.1	4	1.00	15.38
27	2.00	33211	19.6	20.5	0	3.00	100.00
27	2.00	33311	18.4	15.0	0	2.00	70.00
28	2.00	31211	12.8	14.3	0	3.00	100.00
28	2.00	31311	14.4	16.2	0	2.00	66.67
28	2.00	32261	13.2	16.1	0	3.00	70.00
28	2.00	32321	14.3	13.7	8	1.00	0.0
28	2.00	33211	16.0	18.6	2	2.00	81.82
28	2.00	33311	18.9	19.3	7	1.00	36.36
29	1.00	31211	11.6	13.6	0	3.00	100.00
29	1.00	31311	13.2	11.8	0	2.00	46.15
29	1.00	32261	10.8	14.9	0	3.00	60.00
29	1.00	32321	15.8	20.6	0	2.00	36.36
29	1.00	33211	18.7	19.5	3	2.00	100.00
29	1.00	33311	15.9	17.3	6	2.00	70.00
30	1.00	31211	10.3	13.4	0	3.00	72.73
30	1.00	31311	9.9	9.4	0	1.00	13.33
30	1.00	32261	13.0	14.5	0	3.00	87.50
30	1.00	32321	13.6	14.8	4	2.00	20.00
30	1.00	33211	15.2	15.2	2	2.00	80.00
30	1.00	33311	18.8	19.8	9	1.00	83.33
31	2.00	31211	14.3	16.8	0	3.00	72.73
31	2.00	31311	12.6	15.6	4	2.00	33.33
31	2.00	32261	14.0	17.7	0	2.00	87.50
31	2.00	32321	15.5	16.1	4	2.00	25.00
31	2.00	33211	18.9	20.5	2	2.00	90.00
31	2.00	33311	15.3	18.3	9	1.00	37.50
32	2.00	31211	14.9	14.6	0	3.00	88.89

32	2.00	31311	13.2	14.8	0	3.00	90.91
32	2.00	32261	12.2	14.3	0	3.00	75.00
32	2.00	32321	14.6	21.6	4	1.00	0.0
32	2.00	33211	19.2	20.0	0	3.00	100.00
32	2.00	33311	19.9	22.0	3	2.00	80.00
33	1.00	31211	16.6	17.3	2	2.00	50.00
33	1.00	31311	16.4	19.1	0	2.00	50.00
33	1.00	32261	14.5	18.6	2	2.00	85.71
33	1.00	32321	17.1	22.6	2	1.00	16.67
33	1.00	33211	20.8	18.0	5	1.00	66.67
33	1.00	33311	18.3	18.4	9	1.00	22.22
34	1.00	31211	12.3	13.8	0	3.00	87.50
34	1.00	31311	14.3	18.1	0	2.00	35.71
34	1.00	32261	14.3	17.4	2	3.00	85.71
34	1.00	32321	14.3	17.7	0	2.00	30.77
34	1.00	33211	19.1	19.9	0	3.00	100.00
34	1.00	33311	17.5	20.5	6	1.00	45.45
35	2.00	31211	10.9	12.8	0	3.00	100.00
35	2.00	31311	13.4	14.5	2	2.00	25.00
35	2.00	32261	12.9	15.5	0	2.00	45.45
35	2.00	32321	14.4	16.7	0	2.00	25.00
35	2.00	33211	17.1	17.9	0	3.00	100.00
35	2.00	33311	18.2	19.2	5	2.00	60.00
36	2.00	31211	12.1	12.9	4	3.00	100.00
36	2.00	31311	13.3	15.3	0	2.00	46.15
36	2.00	32261	13.5	17.1	0	2.00	55.56
36	2.00	32321	15.0	21.2	0	1.00	11.76
36	2.00	33211	15.8	15.0	0	3.00	90.00
36	2.00	33311	18.1	16.0	4	2.00	54.55
37	1.00	31211	11.1	12.5	2	3.00	100.00
37	1.00	31311	12.1	14.7	0	3.00	69.23
37	1.00	32261	12.5	14.5	0	3.00	60.00
37	1.00	32321	12.2	18.3	2	2.00	46.15
37	1.00	33211	17.8	18.6	2	3.00	100.00
37	1.00	33311	17.0	18.3	2	2.00	80.00
38	2.00	31211	17.4	19.4	4	2.00	100.00
38	2.00	31311	14.3	15.1	2	3.00	100.00
38	2.00	32261	12.4	15.5	0	2.00	75.00
38	2.00	32321	16.2	17.8	4	2.00	33.33
38	2.00	33211	23.2	17.9	2	1.00	66.67
38	2.00	33311	20.1	18.8	5	1.00	75.00
39	2.00	31211	16.1	18.1	0	3.00	100.00
39	2.00	31311	16.5	14.9	4	2.00	50.00
39	2.00	32261	12.1	17.0	0	3.00	87.50
39	2.00	32321	19.3	20.2	6	1.00	16.67
39	2.00	33211	19.9	20.1	3	2.00	88.89
39	2.00	33311	18.3	21.1	8	1.00	25.00
40	1.00	31211	16.3	17.8	2	2.00	87.50
40	1.00	31311	16.5	17.5	6	2.00	85.71
40	1.00	32261	14.7	14.1	0	2.00	100.00
40	1.00	32321	15.7	18.0	0	2.00	36.36
40	1.00	33211	20.8	20.9	0	2.00	90.00
40	1.00	33311	17.1	17.3	4	2.00	66.67
41	1.00	31211	13.1	14.1	0	3.00	100.00
41	1.00	31311	14.5	17.9	2	2.00	72.73
41	1.00	32261	15.2	17.8	2	2.00	183.33
41	1.00	32321	18.2	22.1	0	1.00	15.38
41	1.00	33211	18.3	17.2	0	2.00	90.00
41	1.00	33311	19.6	15.5	7	1.00	42.86
42	2.00	31211	15.0	16.8	2	2.00	87.50
42	2.00	31311	12.9	14.2	0	3.00	75.00
42	2.00	32261	11.0	13.4	0	3.00	55.56
42	2.00	32321	16.1	17.8	0	2.00	50.00

42	2.00	33211	20.3	21.1	2	2.00	100.00
42	2.00	33311	17.9	15.6	9	1.00	57.14
43	1.00	31211	13.9	13.4	0	3.00	100.00
43	1.00	31311	16.0	18.5	4	2.00	70.00
43	1.00	32261	12.7	17.4	2	2.00	66.67
43	1.00	32321	15.2	15.1	0	2.00	33.33
43	1.00	33211	19.9	20.7	2	2.00	100.00
43	1.00	33311	17.3	18.9	8	1.00	30.00
44	1.00	31211	12.5	14.8	0	3.00	72.73
44	1.00	31311	15.5	20.2	0	2.00	69.23
44	1.00	32261	14.7	18.8	0	2.00	66.67
44	1.00	32321	18.7	20.9	0	2.00	45.45
44	1.00	33211	19.4	20.3	0	3.00	100.00
44	1.00	33311	21.8	20.7	4	1.00	87.50
45	1.00	31211	13.4	15.5	0	3.00	100.00
45	1.00	31311	13.7	18.9	0	2.00	64.29
45	1.00	32261	13.2	16.8	0	3.00	100.00
45	1.00	32321	15.0	13.1	6	2.00	37.50
45	1.00	33211	20.3	21.1	0	2.00	100.00
45	1.00	33311	20.6	21.4	4	2.00	100.00
46	2.00	31211	13.7	16.3	0	3.00	100.00
46	2.00	31311	12.3	14.2	2	3.00	72.73
46	2.00	32261	11.9	13.4	0	3.00	75.00
46	2.00	32321	15.5	17.8	2	2.00	33.33
46	2.00	33211	20.8	21.7	0	2.00	100.00
46	2.00	33311	20.0	20.6	1	2.00	80.00
47	2.00	31211	14.7	14.6	0	3.00	100.00
47	2.00	31311	16.1	16.4	4	2.00	45.45
47	2.00	32261	13.2	16.6	0	3.00	87.50
47	2.00	32321	17.0	20.4	8	1.00	14.29
47	2.00	33211	20.3	22.0	3	2.00	90.00
47	2.00	33311	19.5	20.2	7	1.00	55.56
48	1.00	31211	13.5	13.1	0	3.00	100.00
48	1.00	31311	13.0	13.8	0	3.00	100.00
48	1.00	32261	11.3	12.7	0	3.00	75.00
48	1.00	32321	16.0	20.5	2	2.00	41.67
48	1.00	33211	21.0	20.2	0	2.00	90.00
48	1.00	33311	18.1	22.4	8	1.00	44.44
49	1.00	31211	11.5	12.8	0	3.00	88.89
49	1.00	31311	11.9	12.3	0	3.00	63.64
49	1.00	32261	14.3	17.5	0	3.00	87.50
49	1.00	32321	17.1	20.1	0	2.00	45.45
49	1.00	33211	18.4	19.2	2	2.00	100.00
49	1.00	33311	19.5	22.7	5	2.00	80.00
50	1.00	31211	14.6	14.4	0	3.00	100.00
50	1.00	31311	13.3	15.7	0	3.00	83.33
50	1.00	32261	12.5	15.5	0	3.00	87.50
50	1.00	32321	15.4	20.6	0	2.00	50.00
50	1.00	33211	20.3	21.1	0	2.00	100.00
50	1.00	33311	16.0	15.4	9	1.00	37.50
51	2.00	31211	12.4	11.9	0	3.00	100.00
51	2.00	31311	12.3	14.2	0	3.00	90.91
51	2.00	32261	11.9	14.1	0	3.00	87.50
51	2.00	32321	13.1	15.7	0	2.00	50.00
51	2.00	33211	20.2	21.1	1	2.00	100.00
51	2.00	33311	19.7	21.3	0	2.00	90.91
53	2.00	31211	14.4	14.2	6	2.00	50.00
53	2.00	31311	14.1	15.6	0	3.00	81.82
53	2.00	32261	12.1	15.1	2	3.00	77.78
53	2.00	32321	18.7	23.2	6	1.00	50.00
53	2.00	33211	21.2	22.0	0	2.00	100.00
53	2.00	33311	19.2	21.1	6	1.00	87.50
54	1.00	31211	15.2	15.0	0	3.00	100.00

54	1.00	31311	14.0	17.2	0	2.00	69.23
54	1.00	32261	12.4	15.9	0	3.00	66.67
54	1.00	32321	17.1	20.0	0	2.00	23.08
54	1.00	33211	21.5	20.8	0	2.00	90.00
54	1.00	33311	21.6	22.5	4	1.00	77.78
55	1.00	31211	13.3	15.8	0	3.00	90.91
55	1.00	31311	12.2	16.2	0	2.00	64.29
55	1.00	32261	12.1	13.9	0	3.00	55.56
55	1.00	32321	15.7	16.2	0	2.00	15.38
55	1.00	33211	21.5	21.0	0	2.00	90.00
55	1.00	33311	17.6	16.9	6	1.00	44.44
56	2.00	31211	12.3	14.0	0	3.00	100.00
56	2.00	31311	14.6	16.7	2	.00	90.00
56	2.00	32261	12.8	14.8	0	.00	100.00
56	2.00	32321	16.2	24.9	2	1.00	25.00
56	2.00	33211	20.7	19.7	2	2.00	88.89
56	2.00	33311	18.6	18.5	6	1.00	55.56
57	1.00	31211	12.7	13.8	0	3.00	100.00
57	1.00	31311	18.2	17.7	2	2.00	27.27
57	1.00	32261	11.2	14.5	0	3.00	75.00
57	1.00	32321	15.4	0.0	6	1.00	0.0
57	1.00	33211	22.3	23.1	1	2.00	100.00
57	1.00	33311	19.2	20.6	6	2.00	85.71
59	1.00	31211	12.8	13.0	0	3.00	61.54
59	1.00	31311	12.6	13.5	0	3.00	81.82
59	1.00	32261	12.8	16.7	2	3.00	77.78
59	1.00	32321	16.3	21.2	0	1.00	12.50
59	1.00	33211	16.9	17.7	0	3.00	100.00
59	1.00	33311	18.0	19.7	5	2.00	70.00
60	2.00	31211	16.1	16.0	2	2.00	100.00
60	2.00	31311	11.3	19.5	4	1.00	14.29
60	2.00	32261	14.9	16.1	6	2.00	57.14
60	2.00	32321	13.7	0.0	12	1.00	0.0
60	2.00	33211	18.8	18.1	2	2.00	58.33
60	2.00	33311	11.8	18.9	13	1.00	28.57

APPENDIX P

Subject Comments

TOPGUN Comments

1. TOPGUN was easier than ICOFT as far as being able to spot targets. ICOFT's vision screen was not very good.

2. I feel the TOPGUN simulator was at some times inconsistent. What worked on the shot before did not always work on the next shot.

3. The TOPGUN simulator trains the operator to aim a little high.

4. I had a good time and got some good information and knowledge out of it.

5. I really liked it, but the real one was phenomenally harder than the TOPGUN.

6. I thought the TOPGUN was not difficult enough to provide a good basis for performance on ICOFT.

7. The controls on ICOFT were a little more sensitive than TOPGUN.

8. Thought the secondary sight with the numbered reticle was more accurate even with having it to lead moving targets.

9. I think that the biggest benefit from TOPGUN was learning to feel the controls, not the actual targets.

10. Lost the effect of having to use one eye in sight, which also makes the controls tougher to find in a hurry.

11. TOPGUN helped in training for the cadillacs but the screen should have been changed to more resemble the ICOFT. Also, the first simulators [part-task] needed to be modified to act (jump around) like the GE version.

12. TOPGUN was too easy. There should have been a much more rigorous setup as you advance through the TOPGUN program.

VIGS Comments

1. VIGS was more closely related to ICOFT than TOPGUN. Also I had a hard time tracking targets on VIGS. Some targets I thought I was zeroed in on, I missed completely.

2. Out of the two, at first, I would say VIGS was the more realistic. The intensity and grading system helped.

3. VIGS was harder than TOPGUN, I thought, but the ICOFT blew both of them away.

4. VIGS is much better than TOPGUN, however it is still far from ICOFT. It may be better if we can wear a headset when we work up with VIGS. Moreover, the training of condition with ICOFT is much different (dark and hot rooms).

5. VIGS shares many similarities with ICOFT.

6. THe ICOFT was very different from VIGS. The controls are in different places and the commander voice on ICOFT was almost completely not understandable. In a real life situation, or for a more realistic experiment, much more training is needed to be done before practicing on ICOFT. The movement over the hills that ICOFT does is very important and some prior training would have been very helpful.

7. I liked VIGS because I felt it was more intense and challenging.

8. I actually preferred the VIGS training to ICOFT. I felt that the fact that both tanks moved made a more realistic mission. It also made it more challenging.

9. The VIGS system was more similar to the ICOFT in that it used the monocular view finder.

10. Once again I thought that "VIGS" was much too easy, it should involve a much harder starting stage and become increasingly more difficult as you proceed.

11. If you could let the trainee listen to the voice saying most of the command words, it would allow the trainee to get used to the voice.

12. VIGS was a good simulator of ICOFT. I believe that the printout is a good motivational factor and training aid.

APPENDIX Q

TOPGUN and VIGS Device Deficiencies Found During the Transfer Study

T O P G U N

1. The engagements on TOPGUN are generally too easy.
2. The kill zone (100%) is too easy/liberal.
3. The second target in the scenario is not "noticed" by the artificial TC.
4. TOPGUN says "cease fire" twice when the "moving ammo" message is displayed.
5. Minimal lead is sometimes necessary even in primary and thermal moving engagements.
6. Occasionally, even though the round is seen as hitting the target, no effect is realized (the target is not killed).

<u>Data Coding Issues</u>

1. Reticle Aim (azimuth and elevation) figures are sometimes greater when the subject hits the target than when the subject misses.
2. The azimuth and elevation criteria to hit the presented targets are not consistent.

V I G S

1. VIGS differs in the fire commands from TOPGUN, giving a second "fire" signal when multiple targets are presented.
2. VIGS has numerous trees in the display; this affects the subjects' ability to hit targets as well as the timing of various parameters.
3. Scenario images must occasionally be clarified.
4. VIGS has periodic "glitches", in which the screen freezes and shakes, while the subject is not given the opportunity to complete the engagement. Also, VIGS sometimes records false operator errors such as "firing before fire command" when the opposite is true.
5. On certain missions (18, 25) VIGS tends to shoot high.

<u>Data coding issues</u>

1. When subjects hit the wrong target first, VIGS gives erroneous readings (showing more than one hit per target).
2. Data scrolls off the screen when the subject fires more than five rounds per mission. In that case, azimuth and elevation readings are lost.
3. The azimuth and elevation criteria to hit the presented targets are not consistent.